GEOLOGY OF THE WAUGH LAKE METASEDIMENTARY COMPLEX, NORTHEASTERN ALBERTA

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GEOLOGY OF THE WAUGH LAKE METASEDIMENTARY COMPLEX,
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ABSTRACT

A complex assemblage of metasedimentary and associated igneous rocks was mapped in the Waugh Lake area of northeastern Alberta and Northwestern Saskatchewan. The complex is considered to be a part of the Tazin-Nonacho metasedimentary band, the absolute age of which is not established.

Petrologic studies have established the major metasedimentary rock types as feldspathic wacke, impure arenite, siltstone, siliceous conglomerate, tuffaceous rocks, schist, phyllonite, and questionable conglomerates. Petrographic classification has established quartz basalt, andesite, diabase, leucocratic granite, and hornblende granite as the igneous rock types in the band.

A "core" of metasedimentary rocks shows relict graded bedding, and samples mainly from this core were used for sedimentation studies. Detailed examination of quartz and feldspar in thin sections indicate that most of the detrital material was eroded from gneissic terrain, and a minor portion of clastic material was derived by reworking of sediments. Heavy mineral study suggests that rocks similar to the Yellowknife geologic province supplied clastic material that gave rise to the Waugh Lake metasedimentary rocks.

Petrologic information indicates that rapid erosion of rugged terrain produced sediments which were transported, and quickly buried in a geosyncline.

Post-depositional history has been complex, involving marked structural and metamorphic changes. Compressional forces have caused isoclinal folding, whereas shear stresses have resulted in mylonites, phyllonites, and crush conglomerates. The grade of metamorphism in the metasedimentary rocks is predominantly middle greenschist facies. The effects of granitization and perhaps boron metasomatism are notable in the Waugh Lake metasedimentary complex.

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CHAPTER I

INTRODUCTION

General Statement

The Precambrian Shield crops out in northeastern Alberta for approximately 6500 square miles, of which 3600 square miles lie north of Lake Athabasca, the remainder south of the Lake.

In 1957, the Research Council of Alberta mapped a portion of the Shield in northeastern Alberta where a band of slightly metamorphosed sedimentary rocks having complex field relationships was revealed in the Waugh Lake Area. Such metasedimentary rocks showing comparable preservation of primary sedimentary features, range of lithologic types, and complexity of structure had not been described by previous workers in northeastern Alberta. The Waugh Lake Area thus seemed unique, and has remained a region of considerable interest, resulting in revisits during the course of subsequent field seasons.

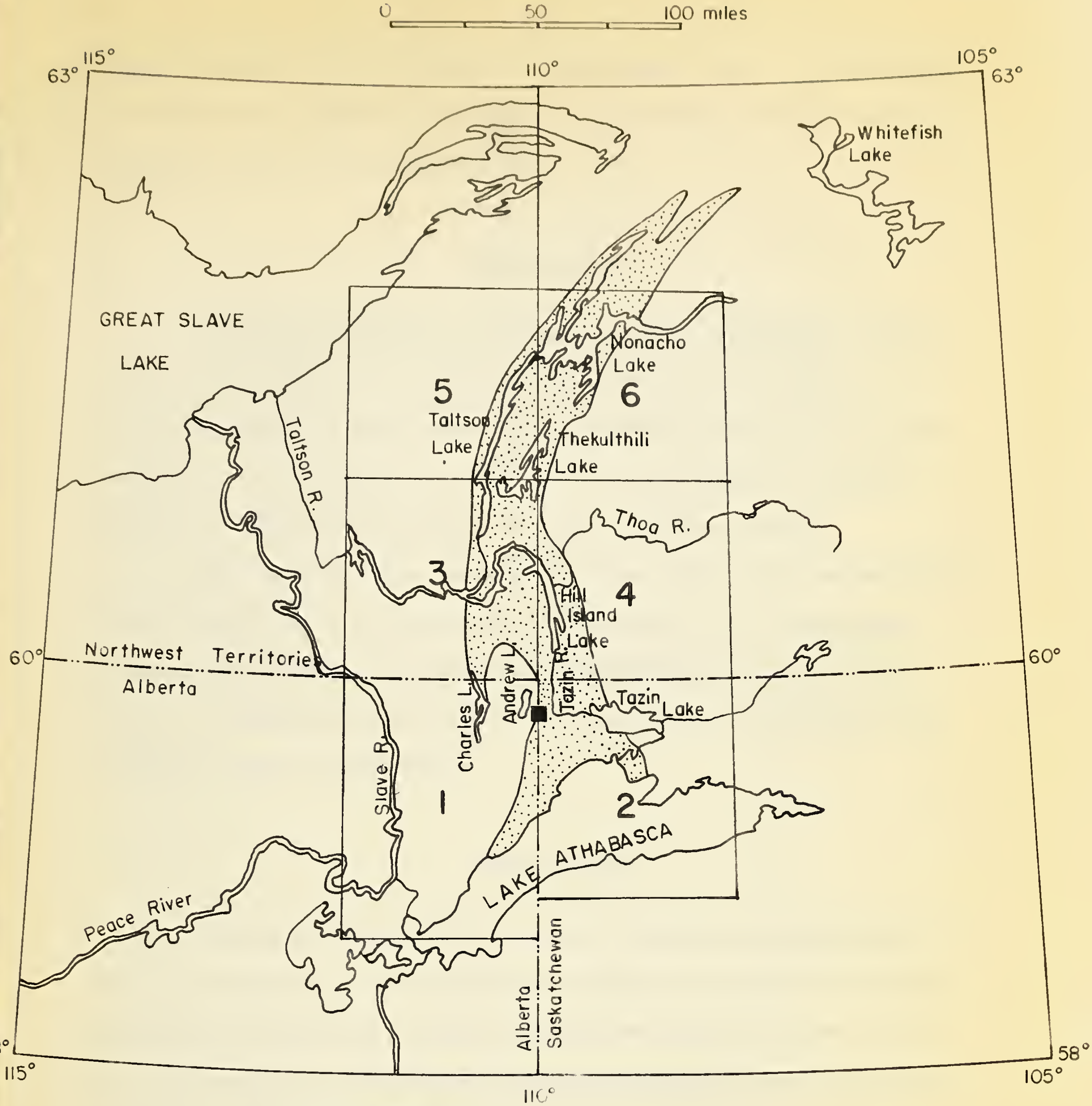
An attempt is made to summarize available field information by presentation of a geological map and detailed description of map-units based largely on 1960 field data. Laboratory studies involved a refinement of lithologic classification, investigation of sedimentation aspects, and metamorphism. Approximately 150 thin sections were examined to facilitate these studies.

Size and Location of Area

The Waugh Lake map-area approximates a square and has an areal extent of nearly 20 square miles. It lies in the extreme northeast

Figure 1 GENERAL LOCATION MAP

Scale: 50 miles to 1 inch



LEGEND:

- ■ Thesis Area
- Precambrian Metasedimentary Rock Band
- 1 Fort Fitzgerald map sheet
- 2 Tazin Lake map sheet
- 3 Fort Smith map sheet
- 4 Hill Island Lake map sheets
- 5 Taltson Lake map sheet
- 6 Nonacho Lake map sheet

corner of Alberta, and overlaps into Saskatchewan (fig. 1). Limits of the map-area are defined by latitudes 59°47'30" and 59°51'30", and by longitudes 109°57'00" and 110°05'00".

Physiography

In general character, the Waugh Lake Area approximates typical Shield physiography--low undulating topography, numerous swamps, discontinuous drainage, sand areas, glacial scouring effects, and abundant vegetation. A comprehensive account of the physiography and glacial features in northeastern Alberta is given by Godfrey (1958a).

West of Waugh Lake, three sand plains obscure much bedrock, and east of Waugh Lake a linear north-trending swamp is the outstanding physiographic feature. The most striking topographic feature of the area is a steep-sided knob (Plate I-3) rising about 100 feet from the southeast shore of Waugh Lake.

Previous Work

Mapping by Camsell (1916) along the Taltson and Tazin Rivers led to the introduction of the term Tazin to refer to the series of highly metamorphosed sedimentary rocks which crop out along the river system. F.J. Alcock (1915, 1936) mapped Tazin metasedimentary rocks in the Lake Athabasca region in Saskatchewan.

In Alberta, reconnaissance mapping of the Shield area north of Lake Athabasca was initiated by Cameron and Hicks (Cameron, 1930; Cameron

and Hicks, 1931; Hicks, 1930, 1932). Collins (1954) of the Research Council of Alberta carried out an investigation of uranium showings in Alberta, where principally low-grade mineralization was found. In 1959 G.C. Riley of the Geological Survey of Canada carried out reconnaissance mapping of the Precambrian area in Alberta north of Lake Athabasca.

Detailed mapping (4 inches to 1 mile) of the Precambrian Shield in northeastern Alberta was initiated in 1957 by J.D. Godfrey of the Research Council of Alberta. Godfrey (1958b) is the first to define the areal extent of the Waugh Lake metasedimentary complex. Previous to 1960, field mapping in the Waugh Lake area had been carried out for short periods in 1957 and 1958.

In 1960, F. Koster of the Saskatchewan Department of Mineral Resources mapped the area east of Waugh Lake in Saskatchewan (unpublished).

CHAPTER II

GENERAL GEOLOGY

General Statement

Regionally, the Waugh Lake metasedimentary rocks lie along the western margin of the north-trending Precambrian metasedimentary band extending from the north shore of Lake Athabasca to approximately 30 miles south of the east arm of Great Slave Lake. Portions of this band were mapped by Cameron and Hicks (see Previous Work) the Fort Fitzgerald map-area; F.J. Alcock (1936) the Tazin Lake Sheet; J.T. Wilson (1941) the Fort Smith area; R. Mulligan (1956) the Hill Island Lake (west half) map-sheet; and J.F. Henderson (1939) the Taltson Lake and Nonacho Lake areas. F.C. Taylor (1959) mapped portions of the Nonacho Lake map-area. The General Location Map (fig. 1) shows the relative positions of these map-areas.

J.T. Wilson mapped the metasedimentary rocks of the Fort Smith map-area as the Tazin Group of Archean age, whereas Henderson mapped the continuation of the same band of metasedimentary rocks in the Taltson Lake and Nonacho Lake map-areas as Proterozoic in age, and referred to them as the Nonacho Group. It is not readily understood why it has been suggested that the rocks comprising the northern and southern portions of this regional band of rocks should be so different in age. Personal communication with R.A. Burwash has led the writer to believe that

difference in metamorphic grade and sedimentary facies give rise to an apparent difference in interpreted age. Much of the terrain adjacent to this band consists of gneiss, schist, and largely undifferentiated granitic rocks.

The Waugh Lake metasedimentary rocks comprise a triangular area with a north-trending axis. Granite gneiss lies to the east, and granitoid rocks lie to the west, north, and south. Structural and lithologic relationships are complex within the metasedimentary band. The central portion of the map-area consists of quartzite, siltstone, wacke and schist, with relict primary sedimentary structures (Plate II-1,2). East and west of this relatively slightly metamorphosed central area the rocks become more massive with rare primary sedimentary structures. The southwest quarter of the map-area contains large amounts of metamorphosed lava flows of basic to intermediate composition with intimate mixtures of tuffaceous metasedimentary rock, impure quartzite, and schist. A second major band of volcanic rock occupies the north-central region. A body of amphibolite in the south-central region stands as a topographic high (Plate I-3); its shape, size and location is suggestive of a volcanic plug, however, its genetic relationship with the basic rock bodies is unknown. Elongate bodies of a sheared inequigranular rock with a sericitic matrix form a considerable portion of the western edge of the map-area; this map-unit appears to be a sheared conglomerate, but it is mapped as a sericitic, porphyroclastic phyllonite.

Several small elliptical igneous bodies of granitic composition intrude the metasedimentary complex in the central area. These plug-like

bodies may be related to the linear body of sheared leucocratic granite along the eastern edge of the map-area. A small diabase dyke a quarter of a mile north of Waugh Lake transects the metasedimentary rocks.

The effects of dynamic metamorphism are more evident in the incompetent beds where phyllonites have resulted from shearing. Most faults trend parallel to foliation. Metasedimentary units and foliation trend north and steep to vertical dips are characteristic throughout the area (Plate I-1).

Stratigraphy as Related to Possible Structural Complexities

Approximately 20,000 feet of Tazin metasedimentary rocks comprise the stratigraphic section in the Waugh Lake Area (refer to fig. 8--Geological Section). Included in this total thickness is basic rock map-unit consisting of interlayered fine-grained basic to intermediate flows, tuff, schist, and quartzite. It should be emphasized that folding and faulting may have caused repetition or omission of beds.

A central zone of metasedimentary rocks on both sides of Waugh Lake shows preservation of bedding, and graded bedding was used for top determinations. On the west side of Waugh Lake, five top determinations indicate a stratigraphic sequence progressively younger to the west; of another five top determinations on the east side of the lake, two indicate the top of the stratigraphic section lies to the east. This information combined with foliation dips which are mainly westerly on the west side of the lake, and easterly on the east side of the lake suggest the existence of a fold structure with an axis approximately along the length

Table 1

Precambrian Rock Sequence*

	Group		Map-Unit***	Map Unit****	
Precambrian	Group III		Diabase Dyke	Granite Pegmatite	Group IV
			White Biotite Granite	Biotite Granite	
	Group II	Tazin** Metasedimentary Rocks	Sericitic Porphyroclastic Phyllonite	Sheared Leucocratic Granite	
			Basic Rocks	Biotite Granite C	
			Amphibolite (plug at southeast corner of Waugh Lake)	Biotite Granite B	
			Granitic Metasedimentary Rocks	Biotite Granite A	
			Siliceous Conglomerate		
			Biotite Schist		
			Quartzite		
	Group I		Biotite Granite Gneiss		

* Map-Units are not arranged in the same order as listed in the legend of the geological map (Map 1).

** The term Tazin is here used in a strict stratigraphic sense, not as a time-stratigraphic unit as used by Alcock (1936); thus the Tazin Metasedimentary Rocks need not be classified as Archean in age.

*** Map-Units are listed in three groups. Groups are arranged chronologically. Map-Units of any one Group are not necessarily arranged chronologically.

**** Map-Units of uncertain stratigraphic position.

of Waugh Lake. Thus, a simple stratigraphic succession cannot be assumed.

Another fold complicating the stratigraphic succession is postulated in the southwest quarter of the map-area where the large basic body may represent the core of a large isoclinally folded syncline which plunges to the south. Top determinations indicate younger beds lie to the west on the eastern margin of the basic body, which, combined with the converging nature of foliation strikes support the postulated synclinal structure.

The discontinuity of outcrops and structural complexities make correlation of suitable marker horizons hazardous. To a considerable extent correlation may be improved by more detailed mapping and along-strike traversing.

Standard Reference Rocks

A five-fold division of metasedimentary rock types was established in the course of field mapping, however, petrographic analyses of representative specimens gave rise to a more detailed laboratory classification. Seven metasedimentary rock samples were chosen as standard reference rocks from about 300 hand specimens. Selection of these standards to represent petrologically distinct metasedimentary rock types was based primarily on thin section examination and to a lesser extent on hand specimen characteristics. Two fine-grained lava flows have been selected as standard reference rocks. Table 2 shows the relationship between field map-units and the adopted laboratory classification as represented by the standard reference rocks.

Table 2

Map-Units and Their Corresponding Standard Reference Rocks

Field Map-Unit	No. of Thin Sections Examined	Petrographic Classification	Standard Reference Rock Sample No.
Quartzite	60	*Quartzose Siltstone	60-147-2
		*Mica-Quartz Arenite	60-146-1
		*Feldspathic Wacke	60-709-2
Biotite Schist	6	*Phyllonite	60-717-4
		*Phyllonitic Schist	60-723-8
Siliceous Conglomerate	-	---------------------	--------
Sericitic Porphyroclastic Phyllonite	24	*Sericitic, Porphyroclastic Phyllonite	60-132-1
Granitic Metasedimentary Rocks	-	----------------------	--------
Basic Rocks	40	**Quartz Basalt	60-711-5
		**Hybrid Andesite	60-716-9
		*Tuffaceous Metasedimentary Rock	60-716-3

* Williams, Turner and Gilbert (1954)

** Moorhouse (1959)

Maximum care in selection of standards was exercised in anticipation of detailed petrologic investigations on these samples. The standards will be discussed separately in the next chapter with their appropriate map-unit.

CHAPTER III

PETROLOGY AND STRUCTURAL RELATIONSHIPS

General Statement

Each map-unit is discussed in order (from Group I to Group III as presented in Table 1) with regard to (1) field data which includes geographic distribution, hand specimen characteristics, internal structures, and contact relationships, and (2) laboratory information comprising discussion of standard reference rocks and petrographic studies where applicable. Map-units of uncertain stratigraphic position are discussed as one separate group (Group IV).

Discussion of Map-Units

GROUP I

Biotite Granite Gneiss

This map-unit is restricted to the eastern margin of the map-area. Four small lenses of granite gneiss in proximity to the main body occur in the granitic metasedimentary and massive quartzite bodies.

Granite gneiss is pink to red on weathered and fresh surfaces, fine to medium grained, and dense. Felsic minerals predominate, the usual mafic mineral being biotite which forms continuous fine foliation and mafic bands, imparting good gneissic texture to the rock. A zone of mylonite along the western margin of the granite gneiss continues

into leucocratic granite, suggesting the presence of a major fault. Gneissic blocks of amphibolite and schistose mafic lenses occur sporadically in granite gneiss.

Lenticular bodies of granite gneiss in the granitic metasedimentary and quartzite map-units may be more appropriately reclassified as lit-par-lit injection gneiss, not differing greatly from the granitic metasedimentary rocks.

Under the microscope, 2 slides (60-719-3 and 60-719-4) of granite gneiss that were studied show development of porphyroclasts, mortar texture, and bent plagioclase twin lamallae. The rock consists of about 20 per cent quartz, 35 per cent alkali feldspar (microcline and untwinned negative relief feldspars), 25 per cent plagioclase, 5 per cent biotite, and minor amounts of muscovite, chlorite, and epidote. Based on thin section study, this rock is classified as flaser quartz monzonite gneiss.

GROUP II

Quartzite

The quartzite map-unit is distributed throughout the length and width of the metasedimentary band and forms the major metasedimentary rock type. Quartzites were typically fine grained, impure, grey to black on fresh and weathered surfaces, compact to fissile, and massive to well bedded. Schist, phyllite, and phyllonite were always present in the quartzite terrain, outcrops being mapped as quartzite where relatively deficient in schistose rocks. The central area of quartzites (on both sides of Waugh Lake) shows good relict sedimentary bedding, commonly

graded, with individual beds ranging from finely laminated beds 1/8 inch thick to beds 10 inches thick. Finely laminated quartzites tend to be contorted, commonly with development of drag-folds, whereas coarser-grained and thicker beds were more competent, resulting in gentle folds. At times, fracture cleavage was distinct in thicker beds. Crossbedding seemed to be absent in the field, but an example of apparent small-scale crossbedding was seen on a polished slab of sample 60-147-2 (Plate IV-6). Contacts of quartzites with enclosed and adjacent rocks are discussed with the appropriate map-units.

Under the microscope, many of the rocks were classified as feldspathic wacke, whereas only a few arenite and siltstone thin sections were seen. Thus, three standards were selected from the quartzite map-unit: feldspathic wacke (60-709-2), mica-quartz arenite (60-146-1), and quartzose siltstone (60-130-2). The mineralogy of these three specimens is summarized in Table 3.

The standard feldspathic wacke (Plate V-1) is strikingly fresh, showing graded bedding, and excellent preservation of clastic sedimentary fabric. Grains of the coarse fraction are fine sand-size, and largely subangular with lesser amounts of angular and subrounded grains (full discussion of clastic grains is reserved for CHAPTER IV, where size analysis of sample 60-709-2 is treated). The matrix is composed of a fine-grained aggregate of biotite, sericite, quartz, and feldspar, with a few large bent grains of detrital muscovite oriented parallel to bedding.

The standard mica-quartz arenite thin section (Plate V-2) is relatively massive, fine to medium sand-size, and highly recrystallized.

Table 3

Modes* of Standard Reference Rocks from the Quartzite Map-Unit

Minerals	60-130-2**	60-146-1***	60-709-2****
	per cent	per cent	per cent
Quartz	49.5	68.8	54.6
Orthoclase	0.3	-	-
Plagioclase	17.7	2.3	15.9
White mica	20.8	22.3	13.0
Biotite	10.1	1.0	15.3
Chlorite	0.4	3.6	-
Epidote	-	0.1	-
Tourmaline	0.1	0.2	0.4
Zircon	-	-	0.1
Apatite	-	-	0.3
Hematite	1.0	0.7	0.1
Pyrite	0.2	0.9	-
Leucoxene	-	0.1	-
Magnetite	-	-	0.5

* 1000 point counts. Thin sections are stained with sodium cobaltinitrite.

** Quartzose Siltstone.

*** Mica-Quartz Arenite.

**** Feldspathic Wacke.

Sutured grain boundaries and development of strain shadows in quartz grains are obvious effects of metamorphism. The mode (Table 3) shows 22.3 per cent white mica.

The standard quartzose siltstone thin section (Plate V-3) is characterized by fine grain size (0.01 to 0.06 millimetre), finely laminated bedding, and dominance of quartz and mica. Quartzose bands with graded bedding (Plate V-3) alternate with sericite-rich layers in which sericite show aggregate extinction.

Biotite Schist

Biotite schist, as a map-unit, was broadly defined to include all fissile, finely-foliated, micaceous rocks interlayered with relatively lesser amounts of impure quartzite. In the field, it was possible to identify schist, phyllite, and phyllonite with chloritic, biotite-rich, sericitic, and ferruginous varieties, but such subdivisions were too refined to enable correlation on the geologic map. In the map-area, biotite schist occurs as a wide band along the axis of Waugh Lake, whereas away from the lake, only rare lenses and thin bands of schist occur. The schist zone along the length of Waugh Lake may be divided into a northern area extending from the northwest corner of Waugh Lake to the top of the map-area, and a central and southern portion. Schists of the northern area are ferruginous, chloritic, and highly sheared with development of crush conglomerate formed by fracturing and rolling of quartz veins; schists of the central and southern areas are deficient in chlorite, and stresses have given rise to tight

small-scale folds and boudinage structures. Contacts of the central schist zone were commonly sharp, whereas contacts of schist bands away from Waugh Lake were gradational in nature, the criterion for mapping of schist bodies being relative predominance of schist over impure quartzite.

Laboratory studies permitted isolation of typical schistose rocks, from which two samples were selected as standards (Table 4). Based principally on textural features described by Gilbert (Williams, Turner, and Gilbert, 1955) thin section 60-717-4 is classified as a phyllonite, and thin section 60-723-8 is classified as a phyllonitic schist. Thin section 60-717-4 is composed principally of quartz and sericite, with smaller amounts of chlorite, magnetite, and untwinned feldspar; magnetite and chlorite commonly form mafic pods. Shearing effects are shown by microscopic boudinage of quartz veins, development of augen, and prominent development of flow cleavage in sericitic layers. Quartz has largely recrystallized to medium-size grains showing minor strain effects. Thin section 60-723-8 does not show effects of extreme shearing, but strong deformational forces have caused crenulation of former sericitic foliation planes and development of axial plane cleavage. Recrystallization of quartz gave rise to equidimensional, relatively unstrained quartz grains in pods. Other thin sections of schistose rocks show similarity to the standard phyllonitic schist.

Combination of laboratory and field data indicate that major shearing has taken place along a zone of schistose rocks along the axis of Waugh Lake.

Table 4

Modes* of Standard Reference Rocks from the Biotite Schist Map-Unit

Minerals	60-717-4**	60-723-8***
	per cent	per cent
Quartz	36.8	23.8
Plagioclase	0.5	0.6
White Mica	50.8	49.8
Biotite	-	21.5
Chlorite	8.7	0.4
Tourmaline	-	0.5
Apatite	-	0.5
Sphene	-	0.1
Magnetite	3.4	1.1
Hematite	-	2.1

* 1000 point counts. Each thin section stained with sodium cobaltinitrite.

** Phyllonite.

*** Phyllonitic schist.

Siliceous Conglomerate

In the central part of the map-area, just west of the large sand plain, a narrow band of siliceous conglomerate (or quartz-pebble conglomerate) was mapped. This rock is characterized by rounded granules and pebbles of quartz set in a silty matrix showing good bedding. A standard specimen was not selected for this map-unit because samples were too small and inhomogeneous.

Petrographic study of the finer-grained fraction revealed distinct bimodality of grain size, the primary mode lying in the coarse silt-size fraction, and the secondary mode lying in the granule-size fraction. Matrix forms about 60 per cent of the thin section, and consists of quartz, sericite, biotite, chlorite, orthoclase, and plagioclase; granule-sized fragments are rounded to subrounded quartz, quartzite, rod perthite, and questionable hornfelsic fragments. Poikiloblastic flakes of chlorite tend to be concentrated in micaceous layers showing poorly developed false cleavage. Shearing effects may be generally interpreted as being moderate to slight.

Granitic Metasedimentary Rocks

A band of granitic metasedimentary rocks is the easternmost map-unit of the Waugh Lake metasedimentary band, and occurs as an elongate body having a maximum width of half a mile. This map-unit dominantly consists of biotite schist, intimately mixed with medium- to coarse-grained felsic material. Several quartzite lenses were noted, but only one occurrence was sufficiently large to be represented on the

geological map. The whole unit has undergone moderate to severe shearing as shown by development of felsic augen and intense fracturing. Banding, defined by interlayered bands of schistose and felsic material, is straight and continuous with little deviation from northerly strike. These granitic metasedimentary rocks are interpreted as having been derived by injection and assimilation of dominantly schistose country rock by granitic material. The contact with quartzites consists of a relatively sharp lithologic change, whereas the contact with sheared leucocratic granite seems gradational, which would be expected if the granitic metasedimentary rocks are a product of incomplete assimilation by leucocratic granite.

Thin section (60-722-5) from a highly assimilated sample of granitic metasedimentary rock contains 20 per cent quartz, 35 per cent twinned plagioclase, 20 per cent perthite, 8 per cent muscovite, 10 per cent biotite, 5 per cent chlorite; accessory sphene, zircon, pyrite, and hematite form 2 per cent of the slide. Cataclastic texture is shown by fracturing of feldspar grains and development of felsic augen. Feldspar grains are especially interesting because many fractured grains are welded by fresh feldspar. A vein cutting foliation consists of adularia, plagioclase, and quartz with vermicular chlorite. Petrographically, the granitic phase of granitic metasedimentary rocks is classified as sheared quartz monzonite.

Amphibolite

Small amphibolite lenses in biotite granite and biotite granite gneiss, along with a massive plug-like biotite amphibolite body

are the only occurrences in the map-area. Amphibolite lenses are discussed with their host rocks, thus the present discussion deals with only the amphibolite plug-like body lying within the metasedimentary band.

Located at the southeast corner of Waugh Lake, the subcircular amphibolite body, which is about a quarter of a mile in diameter, stands as a topographic high (Plate I-3). The rock is homogeneous and massive, and the main minerals visible in hand specimen are red feldspar, amphibole, quartz, biotite, and chlorite. The plug is in shear contact with rocks along the eastern and western periphery.

Thin section 60-721-8 shows hypidiomorphic-heterogranular texture, consisting of abundant 0.5 to 2 millimetres anhedral to subhedral grains of hornblende and biotite set in a fine-grained felsic groundmass. The thin section consists of 30 per cent alkali feldspar (perthite and microcline), 25 per cent hornblende, 20 per cent quartz, 15 per cent biotite, 7 per cent plagioclase; accessory apatite and sphene form 3 per cent of the rock. Plagioclase and biotite show moderate to high degree of alteration. Petrographically, this rock is classified as hornblende granite.

If this amphibolite body does represent a relict volcanic plug, then the last effusive rocks may have been acidic. Otherwise, it can conceivably represent an intrusive hornblende granite mass.

<u>Basic Rocks</u>

The basic rock map-unit consists of basic to intermediate lavas and/or sills, tuff, tuffaceous metasedimentary rocks, intercalated with

quartzite and schist. Basic rock bodies occupy about one-sixth of the map-area. The major bodies lie in the southwest quarter and north-central regions of the map-area, and relatively small lenses are scattered in rocks west of Waugh Lake. The diabase dyke north of Waugh Lake is described with rocks of Group III.

Subdivision of the rocks of this map-unit was difficult in the field because of their dark-coloured, fine-grained, and generally massive appearance, and apparent lack of pillows and amygdules. Subtle differences recognized in places were not sufficient to divide the basic rocks into distinct members. Macroscopically recognizable minerals are amphibole, feldspar, quartz, biotite and epidote. Streaky foliation defined by biotite, amphibole, or both, was commonly detected.

An attempt was made to determine petrographically the nature of the large southern basic body to clarify classification difficulties encountered in the field. Results of this special study are presented in the chapter dealing with metamorphism.

Thin section analysis permitted more refined subdivisions of the basic rocks, although many of the thin sections were not diagnostic. Based principally on the study of thin sections, two volcanic rock specimens, one from each of the two main basic bodies, were selected as standard reference rocks. In each case, a well preserved texture shows subhedral to euhedral phenocrysts of hornblende and plagioclase feldspar in a felty to subandesitic groundmass (Plate V-4) of plagioclase, biotite, hornblende, and epidote. Some blocky basal sections of hornblende are suggestive of pyroxene pseudomorphs. The composition

Table 5

Modes* of Standard Reference Rocks from the Basic Rocks Map-Unit

Minerals	60-711-5**	60-716-9***	60-716-3****
	per cent	per cent	per cent
Quartz	7.1	2.1	21.1
Orthoclase	-	1.7	8.2
Plagioclase	40.5 (An60)	28.4 (An41)	36.7
Hornblende	20.2	28.0	-
Biotite	18.6	33.2	21.7
White Mica	-	-	0.7
Chlorite	-	-	0.1
Epidote	13.6	4.9	11.0
Calcite	-	0.1	0.1
Sphene	0.2	1.5	0.3
Apatite	-	-	0.4
Leucoxene	-	0.1	-

* 1000 point counts. Each thin section stained with sodium cobaltinitrite.

** Quartz Basalt (southern basic body).

*** Hybrid Andesite (northern basic body).

**** Tuffaceous Metasedimentary Rock.

of plagioclase in the two standards differ considerably, the sample from the northern body (60-716-9) containing intermediate andesine (An_{41}), and the sample from the southern body (60-711-5) containing intermediate labradorite (An_{60}). This may indicate that sample 60-716-9 is andesitic, and sample 60-711-5 is basaltic in compositon. Retrograde metamorphism may have affected these rocks to a considerable extent.

Sample 60-716-3, located in a small basic body west of the main northern basic body, possesses a texture suggestive of pyroclastic origin (Plate V-5), and is designated as the standard reference rock of tuffaceous metasedimentary rocks. The evidence for pyroclastic origin is found in the xenoclastic nature of feldspars, consisting of sharply angular crystal fragments and euhedral crystals, which are commonly zoned, and range up to 5 millimetres in length. Thin sections 60-723-7 and 60-137-4 show similar texture and may also be classified as tuffaceous metasedimentary rocks; Peikert (1961) has described tuffaceous metasedimentary rocks north of the southern body of biotite granite C.

Sericitic, Porphyroclastic Phyllonite

Sericitic, porphyroclastic phyllonite forms an almost continuous body extending from the southern to northern margins of the map-area, and forms the extreme western map-unit of the Waugh Lake metasedimentary band. Other major bodies of this rock-type lie in proximity to the large basic body in the southwest and west-central areas of the map-area. On

Table 6

Modes of Rocks from the Sericitic, Porphyroclastic Phyllonite Map-Unit

	60-132-1*	60-707-3*	60-132-1**
Fragments	per cent	per cent	
Quartz and Quartzite	20	20	
Alkali Feldspar (perthite, microcline, orthoclase)	15	20	
Plagioclase	-	5	
Granitic Rocks	-	5	
Pelitic Metamorphic Rocks	15	-	
Matrix***			per cent
Quartz	30	20	47.9
Alkali Feldspar	5	5	28.4
Plagioclase	3	3	10.6
White mica	7	20	10.0
Biotite	2	2	0.8
Chlorite	1	-	1.1
Epidote	-	tr	0.8
Magnetite	1	-	0.5
Apatite	tr	tr	-

* Modes by visual estimation.

** Mode by point count (1000 points). Individual mineral grains counted in rock fragments. Sample 60-132-1 is the standard reference rock of this map-unit.

*** Matrix arbitrarily defined as all material less than 0.5 mm.

a weathered surface this rock appears to be a sheared conglomerate with rounded granitic boulders up to 10 inches in diameter (Refer to Plate III-2,3). On a fresh surface, granite, argillite, low grade schist, and quartzite fragments were distinguished in a sheared, sericitic matrix rich in felsic minerals (Plate IV-4). This rock-type was generally homogeneous on outcrop scale, but hand specimens varied from felsic to mafic-rich phases, the matrix nevertheless remaining sericitic. Contacts with adjacent rock-types were largely complicated by shearing and lack of good exposures. The contact with biotite granite A may be sheared or it may represent an unconformity. The possibility that the rock under discussion is a sheared conglomerate or alternatively, a rock derived principally from biotite granite A may be solved by further detailed field and laboratory studies of rocks along this important contact. Contacts with quartzites were uncertain, but in places, sericitic porphyroclastic phyllonite appeared to be interfingered and interlayered with quartzite. Basic rocks also showed the same relationships with sericitic, porphyroclastic phyllonite.

Thin section study was restricted to material smaller than cobble size, and matrix was arbitrarily defined as consisting of all fragments less than 0.5 millimetre. Matrix comprises about 50 per cent of the thin sections studied, and consists of predominantly quartz, with smaller quantities of white mica, plagioclase, orthoclase, biotite, and chlorite. Coarse fragments consist of quartz and quartzite, alkali feldspars (microcline, perthite, orthoclase), plagioclase, foliated pelitic metamorphic rocks, and several granitic rock fragments. Thin sections show marked effects of shearing; mortar texture, stretched

and fractured grains, development of porphyroclasts, and sericitized slip surfaces. Late metamorphic effects have given rise to recrystallization of matrix, with occasional development of euhedral feldspar porphyroblasts.

This rock-unit has undergone a complex metamorphic history, and further research is necessary before conclusions can be made regarding its genesis.

GROUP III

White Biotite Granite

Three small plug-like bodies intrude the central area of metasedimentary rocks. The geological map depicts the three bodies as white biotite granite, but restudy of samples indicates that the small northern body west of Waugh Lake should be reclassified as biotite granite C.

The white biotite granite body lying east of the Alberta-Saskatchewan boundary line was selected for laboratory study because a relatively large number of hand specimens are available. This body is massive, fine- to medium-grained, and commonly white in colour, but partly red, the colour being attributable to pigmentation of feldspar. Quartz, feldspar, and biotite are the essential minerals. No metamorphic or structural disruption around the mass was seen in the metasedimentary rocks.

Three thin sections studied from the large granitic body show uniform texture and mineralogy. Averaged values of essential minerals are 25 per cent quartz, 15 per cent microcline, 40 per cent sodic

oligoclase (An_{12-16}), 15 per cent interstitial negative reflief feldspars, 1 to 3 per cent biotite. The occurrence of euhedral to subhedral feldspar phenocrysts in a massive, slightly finer-grained groundmass gives hypidiomorphic-subequigranular texture. The phenocrysts are plagioclase and perthitic microcline, plagioclase commonly showing zoning. Thin section study shows that the variation of rock colour from white to red is directly attributable to degree of alteration of feldspars, red coloration occurring in specimens containing highly altered feldspars.

Moorhouse's (1959, p. 154) petrographic classification establishes this rock-unit as a leucocratic granite.

Diabase Dyke

A diabase dyke about 100 feet wide and continuous for about a quarter of a mile, was mapped along the Alberta-Saskatchewan boundary line about half a mile north of the northern tip of Waugh Lake. It transects the northerly foliation trend of the metasedimentary rocks at an angle of about 45 degrees. The rock was highly altered, massive, medium grained, of medium green colour, and consisted mainly of amphibole and feldspar. The contacts of the dyke with metasedimentary rocks was distinct and discordant with foliation.

Detailed sampling of this dyke was carried out, and two thin sections (58-1033-2 and 58-1033-4) showed that the rock is highly altered with minor shearing effects; subdiabasic texture was noted in thin section 58-1033-2, whereas medium-grained felty texture was noted in thin section 58-1033-4. Hornblende and calcic andesine (An_{46}) are

the main minerals, with small amounts of alkali feldspar and quartz in the groundmass. Plagioclase laths commonly show highly altered cores, a feature interpreted as relict primary zoning.

Petrographic classification established this dyke as diorite.

GROUP IV

Biotite Granite A and Biotite Granite B

Biotite granite A and biotite granite B are discussed together because of common hand specimen characteristics and affinity in the field. These rock types are located along the west margin of the map-area, where granite B occurs as isolated patches within granite A. A small body of granite A was mapped one mile northwest from the north tip of Waugh Lake. A discussion of these two rock-types is given in the report of the Andrew Lake map-area (Godfrey, 1961).

Biotite granite A grades transitionally into biotite granite B, passing from a medium-grained, well foliated (but not banded), biotite-rich rock with 1/2 to 1 inch feldspar porphyroblasts, into a coarser-grained, poorly foliated to granoblastic rock with euhedral 1/2 to 1 inch porphyroblasts. Contact relationships with the Waugh Lake meta-sedimentary rocks are not well established, although faulting has been detected in places. The nature of the contact where sericitic porphyroclastic phyllonite lies adjacent to granite A has been discussed.

Biotite Granite C

Three main bodies of biotite granite C were mapped, two lying in the south-central region, and the other in the north-central region.

Slight but distinctive differences were noted in the rocks comprising the three bodies. The body extending north from the southern edge of the map-area and lying west from the Alberta-Saskatchewan boundary line, may be considered typical granite C since it is the northern extension of the main body lying to the south. [This body was studied by E.W. Peikert (1961) who shows that granite C is a granitization product of rocks found within the Waugh Lake metasedimentary band.] The rocks of this body are fine to medium grained, massive to slightly foliated, medium to dark grey colour on fresh and weathered surfaces, porphyroblastic (1/4 to 1/2 inch), biotite-rich, and quartz-deficient. In contrast, rocks of the northern body are finer grained, porphyroblasts are incipient, and composition is more basic, with larger amounts of biotite and hornblende. The southeastern body is more felsic with porphyroblasts slightly better developed than in the northern body. A small body of granite C at the southeast corner of Waugh Lake is very similar to the typical granite C body.

Shear effects are slight to moderate in all granite C bodies, with more intense shearing restricted to the margins. Contacts with metasedimentary rocks were complicated by shearing, but where disruption was not too marked, interfingering was observed.

Peikert's petrographic study of a typical sample from the south-central body gave the following composition: 30.3 per cent quartz, 5.9 per cent alkali feldspar, 30.0 per cent plagioclase, 26.2 per cent biotite, 1.0 per cent hornblende, 5.4 per cent epidote, and 1.2 per cent accessory minerals. He classified the rock-unit as porphyroblastic micro-granodiorite.

Sheared Leucocratic Granite

Sheared leucocratic granite, located in the eastern part of the map-area, forms a linear body which broadens southward. Generally, the rock was poorly foliated and showed marked granulation of grains. Light coloured minerals predominated, the readily distinguishable minerals being quartz, feldspar, and white mica; biotite occurred in minor amounts. Contact relationships with the rocks to the east and west have been discussed with the granite gneiss and granitic meta-sedimentary rocks, respectively.

The one thin section (60-722-4) contains about 20 per cent quartz, 55 per cent alkali feldspars (microcline, string perthite, and negative relief untwinned feldspars in the groundmass), 15 per cent plagioclase, 5 per cent white mica, and traces of disseminated biotite and chlorite.

Petrographically, the rock is classified as sheared leucocratic granite, the same classification adopted in the field.

Biotite Granite

Biotite granite bodies are located in the extreme south-central region and along the western margin of the map-area. The southern bodies are typically massive to slightly foliated, medium grained, biotite-rich, and have abundant feldspar crystals. Its mineralogy and field association seem to indicate a gradational relationship with biotite granite C. The two western bodies of biotite granite differ from each other and from the southern bodies. The northern granitic boss in

biotite granite A is a massive, medium-grained, biotite-rich variety with pink and red feldspars, and minor sericite, whereas the southern body is similar in general character but has abundant muscovite, and relatively small amounts of biotite. The southern body contains abundant amphibolite lenses.

Granite Pegmatite

Granite pegmatite was virtually absent in the metasedimentary rocks but common in the surrounding granitoid and gneissic rocks where coarse-grained felsic pegmatites of igneous character and poorly defined secretion types occurred. In metasedimentary terrain, pegmatitic material was poorly defined, occurring as irregular quartzose patches and veins 1/2 inch to about 2 feet wide, usually continuous for several feet. In most cases the felsic stringers would be classified as massive quartz veins. In the neighbourhood of the Waugh Lake elbow, quartzose veins and pods commonly contained abundant tourmaline.

CHAPTER IV

SEDIMENTATION INVESTIGATIONS

General Statement

Mapping in highly disturbed Precambrian Shield areas has given rise to a vast number of geological reports integrating field and laboratory data. However, sedimentation studies are notably lacking in view of the usual destruction of primary sedimentary features by the action of diastrophism, metamorphism and metasomatism.

In the Waugh Lake area, discovery of metasedimentary rocks showing relatively good preservation of primary sedimentary features presented an opportunity to attempt sedimentation laboratory studies. The aim was to use conventional sedimentation techniques, modified to suit the availability of appropriate samples, to suggest provenance and conditions of sedimentation

Size Analysis by Thin Section

When size analysis by thin section was at first contemplated, it was felt that such a study may lead to information of source direction, but lack of stratigraphic control obliterated any hope for such a study. Two other approaches were considered: (1) comparison of thin section and sieve size analysis techniques, and (2) size-frequency distribution studies with related statistical size parameter determinations. The former was not attempted because mechanical disaggregation was

rendered impossible by the well indurated and recrystallized nature of the rock samples. Consequently, thin section study was necessarily concerned with size-frequency distribution.

Sample selection for size analysis posed a complex problem because of the recrystallized nature of the metasedimentary rock specimens. Rapid examination of 65 thin sections led to isolation of four that offered good possibilities for precise grain measurements, and of these, only one, thin section 60-709-2, was selected for use because it retained clastic grain boundaries (Plate V-1) to the extent of minimizing operator error and bias.

Under medium power, thin section 60-709-2 shows sharp grain margins, restricted overgrowth development, relatively minor recrystallization, and massive, unsheared appearance. Good preservation of clastic grain boundaries can be largely attributed to the abundance of pasty micaceous matrix. Although angular grains predominate, grain shapes range from very angular to well rounded, Graded bedding is megascopically and microscopically distinct.

The four samples (57-526-1, 60-709-2, 60-712-7, and 60-713-1), which showed moderate to good preservation of clastic grain boundaries, are strikingly similar in mineralogy and texture, and were classified as feldspathic wackes (Williams, Turner, and Gilbert, 1955, p. 292). These samples are situated along the west side of Waugh Lake, and judging by their field relationships, they may be part of the same stratigraphic unit.

Procedure

The thin section was mounted on a mechanical stage, and traverses spaced 0.5 millimetre apart were run perpendicular to bedding; movement along traverses was made in 0.5 millimetre increments. Maximum diameter measurement of grains was performed with a calibrated micrometer eyepiece; only those grains intersecting the mid-point of the micrometer scale were measured.

In an attempt to define the lower limit of measurements and develop consistency where bias was involved, three trial runs, each consisting of 100 measurements, were performed. Optimum resolution was achieved using medium power. Grains were too small for use of low power; on the other hand, detrital grain boundaries were frequently obscured when high power was utilized because reaction of sand-sized clastic grains with the matrix, typical of wackes, was much more apparent. No measurements were performed where recrystallization had destroyed the clastic nature of the grains; in this respect, bias entered the sampling program, but such occurrences were minor in number and thus probably did not unduly distort the final computations.

Length of grains was estimated to the nearest 0.1 micrometer graduation, then each measurement was converted to the equivalent millimetre unit. Using 0.01 millimetre size intervals, size-frequency histograms for each trial run were constructed, then compared to investigate reproducibility of measurements. Good agreement was achieved down to about 0.02 millimetre (5.50 phi units), thus the lower limit of measurements was determined.

Graphical results of trial runs are not presented in the text.

Having established consistency in procedure, it was then possible to confidently carry out 300 additional measurements, the results of which are discussed in subsequent paragraphs. The measurements were grouped into appropriate 0.25 phi size classes, as done by Friedman (1958, p. 400). All measurements less than 5.50 phi units were lumped into one size class.

Results and Discussion

Size distribution data of 300 measurements are presented in Table 7, and using these results, a size-frequency histogram (fig. 2), cumulative curve with arithmetic ordinate (fig. 3), and cumulative curve with probability ordinate (fig. 4) were constructed.

The large amount of matrix posed serious problems in the construction of the graphs and especially the implications drawn from the graphs. Firstly, lumping of measurements greater than 5.50 phi units erased any possibility of detecting a secondary mode in the finest fraction. Secondly, it was not possible to complete the cumulative curves beyond the 75 per cent cumulative level because the finest phi group (>5.50 Ø) constituting 25 per cent of the total population, was not split into 0.25 phi size classes; this inhibited determination of statistical size parameters since many parameters involve 84th and 95th percentile values in computations. This limitation was resolved by using the 75th percentile figure; Friedman (1958, p. 405) also adopted the 75th percentile figure for his calculations of size parameters.

Table 7

Size Distribution Data

Size Intervals (millimetre)	Size Intervals (phi units)	Number of Grains Per Size Interval	Frequency Per Cent
0.250-0.210	2.00-2.25	-	-
0.210-0.177	2.25-2.50	5	1.67
0.177-0.149	2.50-2.75	5	1.67
0.149-0.125	2.75-3.00	6	2.00
0.125-0.105	3.00-3.25	10	3.33
0.105-0.088	3.25-3.50	14	4.67
0.088-0.074	3.50-3.75	17	5.67
0.074-0.062	3.75-4.00	24	8.00
0.062-0.053	4.00-4.25	28	9.33
0.053-0.044	4.25-4.50	37	12.33
0.044-0.037	4.50-4.75	33	11.00
0.037-0.031	4.75-5.00	24	8.00
0.037-0.027	5.00-5.25	17	5.67
0.027-0.022	5.25-5.50	5	1.67
0.022-0.000	5.50- infinity	75	25
Totals		300	99.97

Figure 2

HISTOGRAM

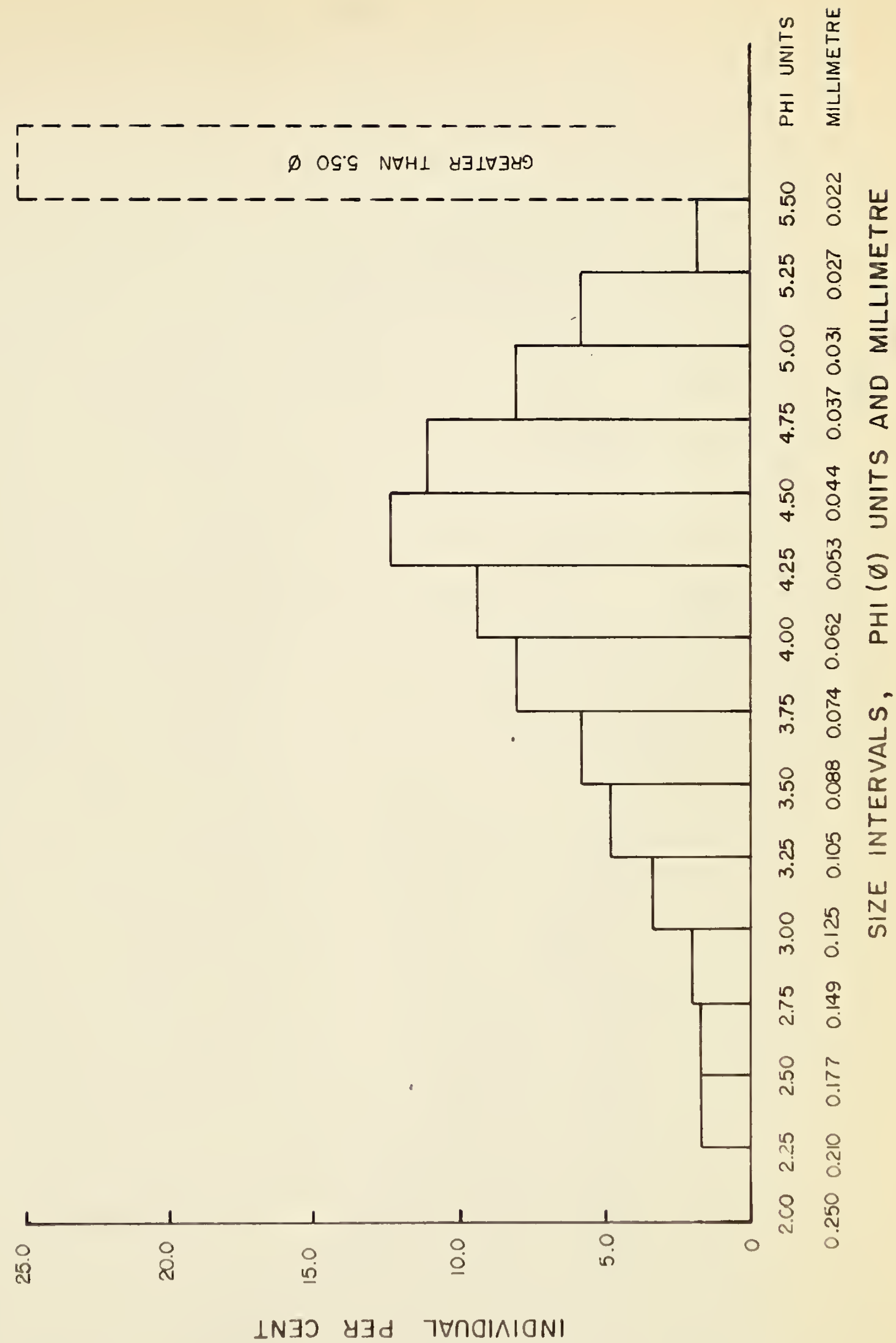


Figure 3

CUMULATIVE CURVE WITH ARITHMETIC ORDINATE

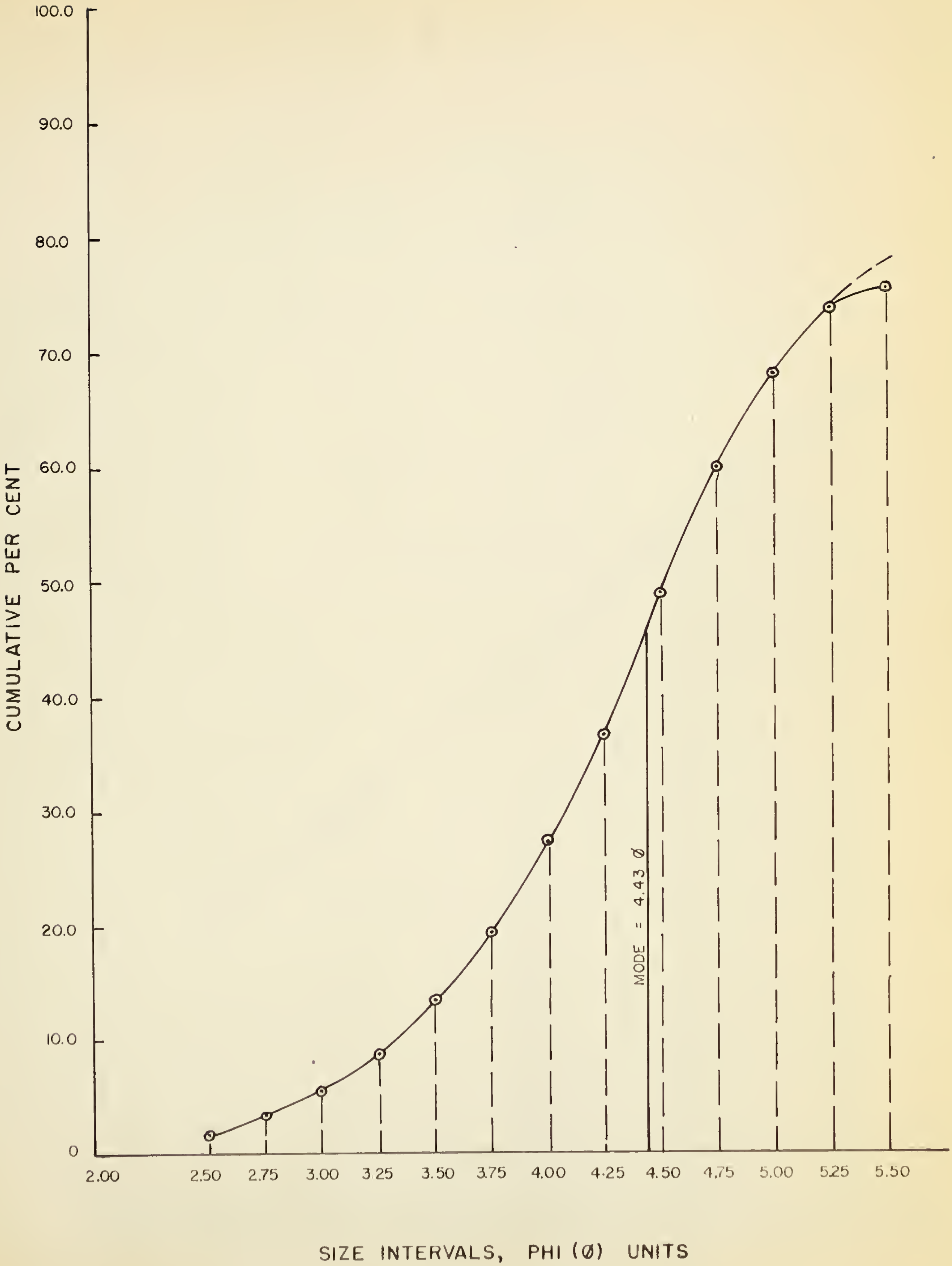
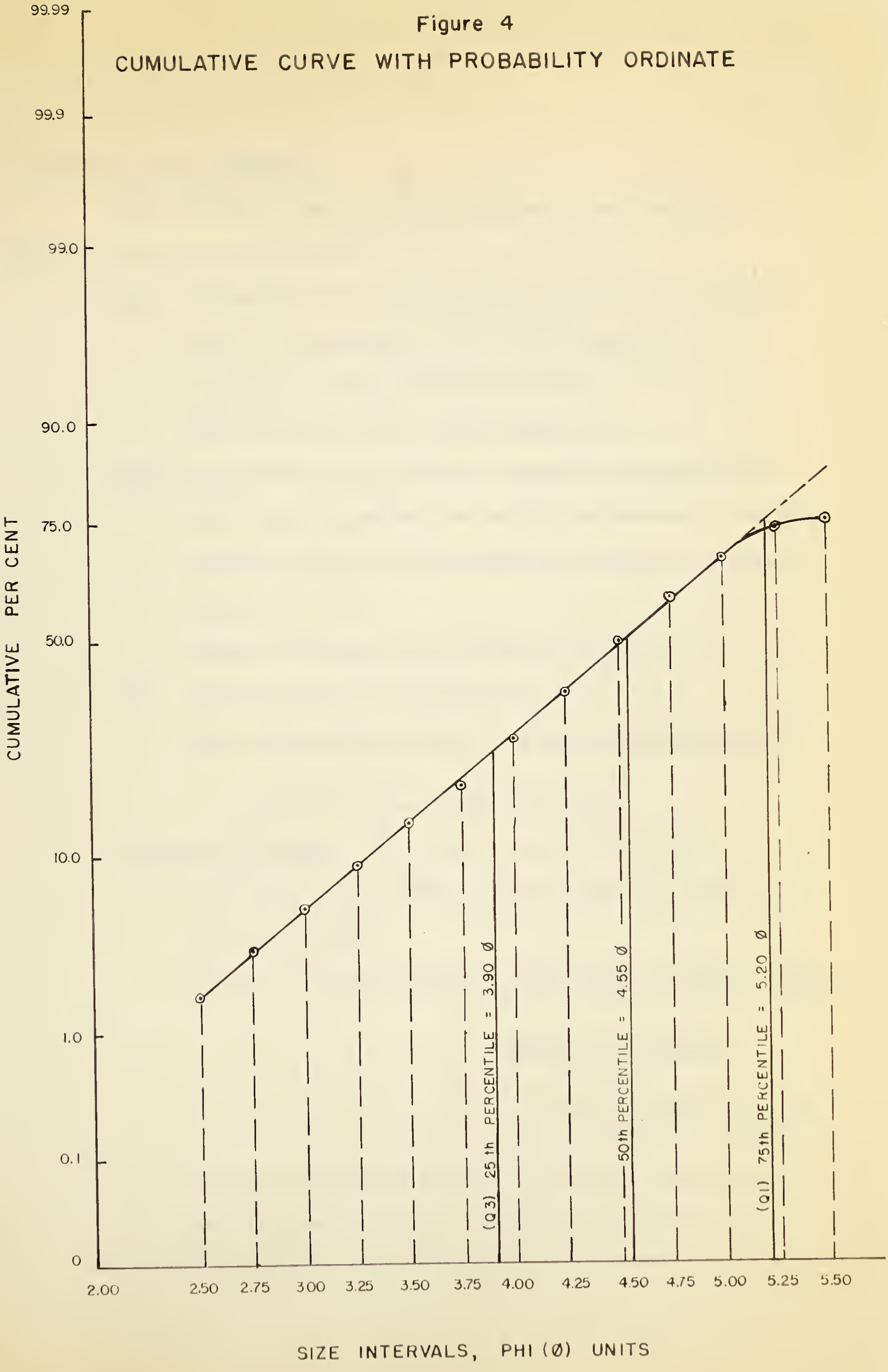


Figure 4

CUMULATIVE CURVE WITH PROBABILITY ORDINATE



Statistical Size Parameters

Calculations of statistical size parameters were based on methods outlined by Folk (1957).

Mode. The mode is the most frequently occurring particle diameter; it corresponds to the inflection point on the arithmetic ordinate cumulative curve.

Mode = 4.43 phi units (0.046 millimetre)

Median. One-half of the grains are coarser and one-half are finer than the median; the median corresponds to the 50th percentile value of the probability ordinate cumulative curve.

Median = 4.55 phi units (0.043 millimetre)

Mean. The mean gives the overall grain size.

$$\text{Mean} = \frac{\phi\,25 + \phi\,50 + \phi\,75}{3} = \frac{3.90\,\phi + 4.55\,\phi + 5.20\,\phi}{3}$$

$$= 4.55 \text{ phi units } (0.043 \text{ millimetre})$$

ϕ Quartile Deviation. This gives a measure of sorting. A relatively large graphic standard deviation would indicate poor sorting.

$$\text{Graphic standard deviation} = \frac{\phi\,75 - \phi\,25}{2} = \frac{5.20\,\phi - 3.90\,\phi}{2}$$

$$= \frac{0.027 \text{ mm} - 0.068 \text{ mm}}{2}$$

$$= -\ 0.020 \text{ millimetre } (5.64 \text{ phi units})$$

A graphic standard deviation of 0.020 millimetre, with mean of 0.043 millimetre, indicates very poor sorting.

Ø Quartile Skewness. This is a measure of asymmetry; it measures the displacement of the median from the average of the 25th percentile and 75th percentile values.

$$\text{Graphic skewness} = \frac{\phi\,25 + \phi\,75 - 2\,\phi\,50}{\phi\,75 - \phi\,25}$$

$$= \frac{3.90\,\phi + 5.20\,\phi - 9.10\,\phi}{5.20\,\phi - 3.90\,\phi}$$

$$= 0.00 \text{ phi units}$$

Zero value for graphic skewness indicates size distribution of the grains is symmetrical.

Kurtosis. Kurtosis gives the degree of peakedness of the histogram, and indirectly designates the ratio of sorting in the "tails" compared to sorting in the central portion of the curve.

For the determination of kurtosis in absolute units, the 95th percentile value is required; this parameter was not determinable in the present study. Nevertheless, Folk (1957, p. GS-H-4) states that if the cumulative curve plots as a straight line on probability paper, then the sample has normal kurtosis (1.00), indicating that the central and "tail" portions of the curve have equally good sorting.

The cumulative curve plotted on probability paper is a straight line for sample 60-709-2, thus it has normal kurtosis up to the 70th percentile at least.

Interpretations

At first glance, the histogram appears to be asymmetrical, with negative skewness (long "tail" toward coarser size fractions). However, it is conceivable that the finest size range would also show a "tail", but this was not determinable by the method of size analysis used in this study. In this respect, Rosenfeld, Jacobsen, and Ferm (1953, p. 120) showed that the character of the histogram beyond 5.00 phi units must be treated with decreased reliability. The low, spread-out nature of the histogram suggests a poorly sorted sediment, a feature common to all wackes. The modal size class was determined to be 4.25-4.50 phi units, or 0.053-0.044 millimetre.

The probability ordinate cumulative curve approximates a straight line (log-normal function), indicating unimodal size distribution (Friedman, 1958, p. 403). The curve shows departure from a straight line in the finest size range; Friedman (1958, p. 403) attributes such a deviation to less reliable analytical data in the finest fraction.

The arithmetic ordinate cumulative curve shows the smooth S-shape that is typically well developed in sediments showing normal symmetrical size distribution. A deviation of abnormal aspect is suggested in the finest size range, but again, imprecision of measurements could account for the digression.

Heavy Minerals

Apparent neglect of heavy mineral studies of Precambrian metasedimentary rocks may reflect the belief that attempts at correlation and provenance determination can lead only to unreliable results because

of the paucity of heavy mineral species in these ancient sediments. The present study is an attempt to identify the heavy mineral species and discuss their significance, but stratigraphic correlation is not attempted in view of the large number of specimens required and the lack of stratigraphic control.

Seven metasedimentary rocks from the standard reference rock suite (Table 2) were crushed in a stainless steel pulverizer to minus 120 mesh. Sieved samples were split using the "quartering by hand" method (Krumbein and Pettijohn, 1938, p. 44). Heavy mineral concentrates were obtained from 20 gram samples using the method summarized in figure 5. Each step is briefly discussed in sequence.

Each 20 gram sample was first divided into light and heavy fractions using pure tetrabromoethane (Sp. Gr. = 2.96), but separation of heavy minerals from metamorphic micas and epidote in heavy fractions was inadequate, necessitating further treatment.

Magnetite was removed with a permanent magnet, making the heavy fraction suitable for further purification with the Frantz magnetic separator. Using settings of slope 15°, tilt 5°, and field strength of 0.35 amperes, the heavy fraction was divided into non-magnetic[1] and magnetic separates. However, after treatment, the non-magnetic separate still contained large amounts of undesirable micas, thus requiring heavy liquid separations with methylene iodide (Sp. Gr. = 3.32).

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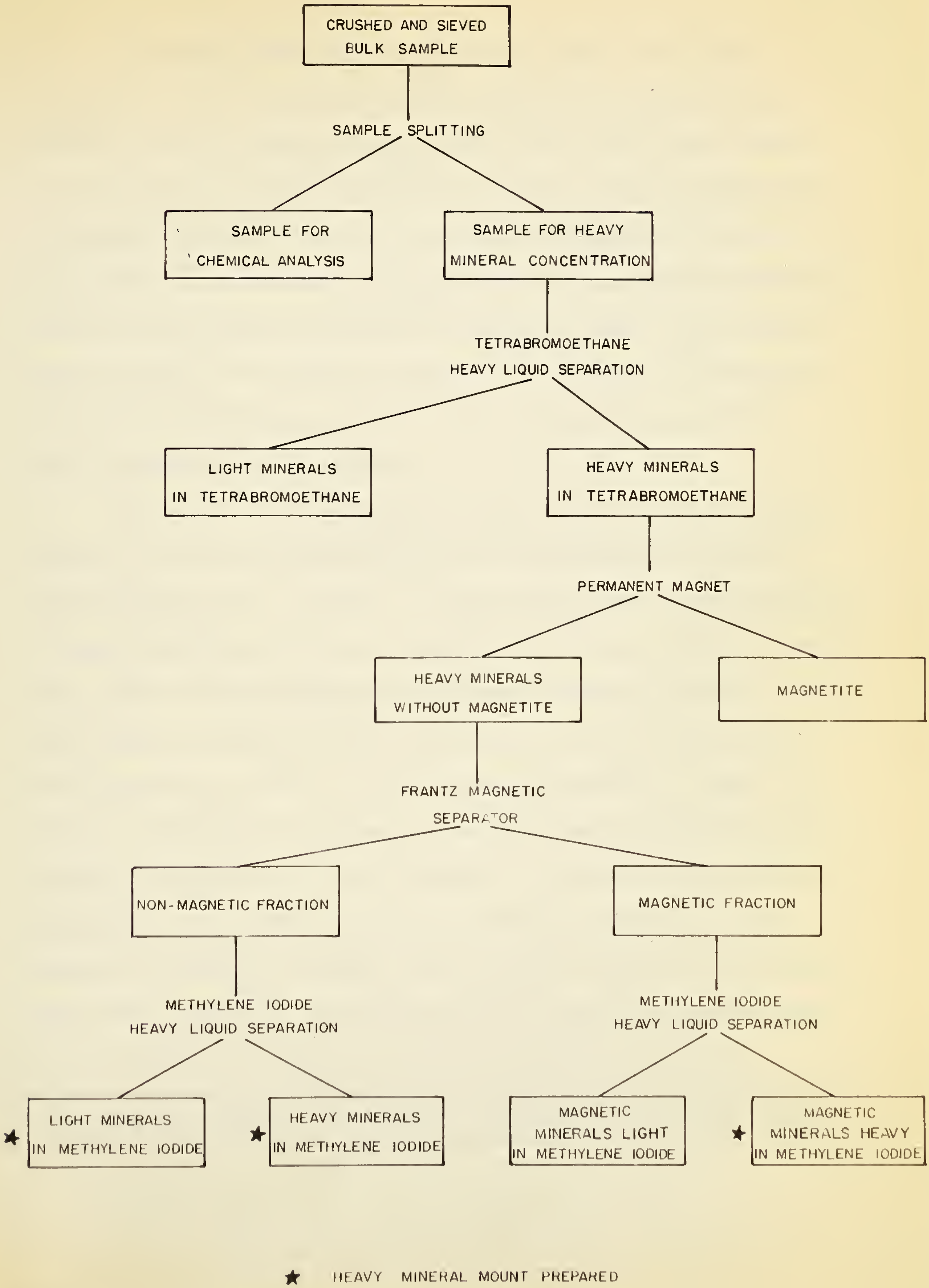
[1] The term non-magnetic is used to refer to the minerals not drawn into the "magnetics" pan when a field strength of 0.35 amperes, and settings of slope 15°, tilt 5° were used.

Figure 5 SCHEME FOR HEAVY MINERAL CONCENTRATION



Methylene iodide separations yielded "light" and "heavy" fractions. At this stage, non-magnetic fractions (light and heavy separates) and the magnetic fraction were weighed and mineral mounts in aroclor (R.I. = 1.67) were prepared. However, dilution effects due to abundant chlorite, biotite, and epidote in the magnetic fraction was anticipated and consequently methylene iodide separations were performed on this fraction also, giving rise to magnetic "lights" and "heavies". Mineral mounts of the magnetic "heavies" were prepared to investigate the presence of moderately magnetic heavy minerals such as garnet, spinel, monazite, and staurolite.

Because of fine grain size and small amount of sample, lengthy settling time was anticipated for heavy liquid separations; hence, a centrifuge was used. A "crust" of light minerals and a "sink" fraction of heavy minerals resulted from centrifuge treatment. However, extremely small (0.01 mm) heavy minerals which tended to form a suspension during centrifuging, contaminated the light separates when the heavy liquid was poured from the tubes. In the subsequent operation, "lights" adhering to the sides of the tubes contaminated heavy minerals that were flushed from the bottom of the containers. A potential source of contamination in all separations was the presence of relatively large amounts of metamorphic minerals such as biotite, chlorite, and epidote. Under these conditions, the weights of heavy mineral[1] separates could not be reliably interpreted, and are not included in the text.

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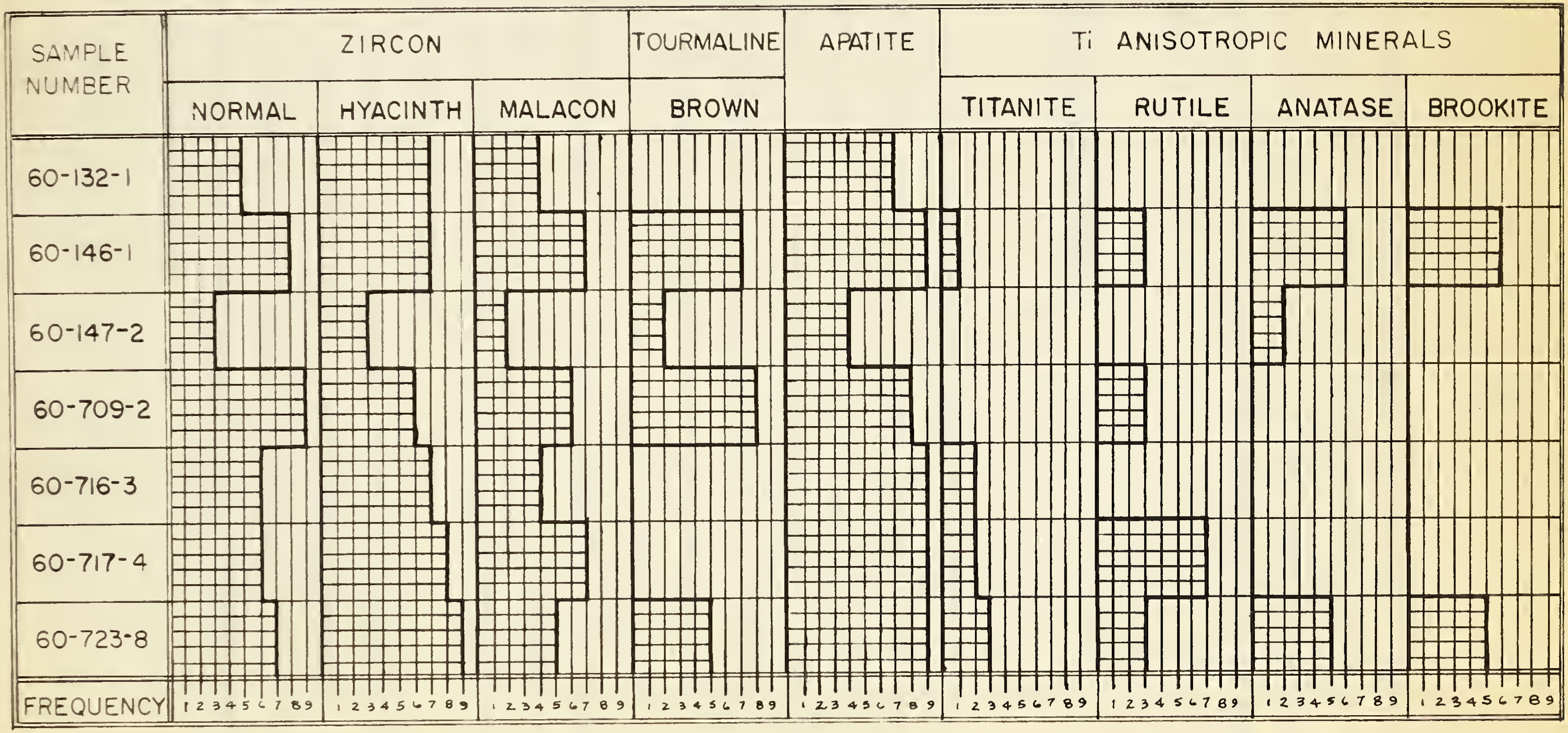
[1] The term heavy mineral is used here to refer to all minerals heavier than 2.96, but excluding micas and epidote.

Figure 6 FREQUENCY DISTRIBUTION OF HEAVY MINERALS



FREQUENCY:

1 = 1 Grain
2 ~ 2-4 Grains
3 ~ 5-10 Grains
4 ~ 10-20 Grains
5 ~ 20-50 Grains
6 ~ 50-100 Grains
7 ~ 100-200 Grains
8 ~ 200-300 Grains
9 > 300 Grains

Petrographic analysis of heavy mineral mounts involved identification of mineral species followed by semiquantitative visual estimation of mineral abundances. For each standard reference rock, three mineral mounts were examined, the cumulative total of each mineral being recorded in figure 6.

Discussion of Heavy Minerals

Zircon

The seven metasedimentary rocks used in this study contained abundant zircons showing great variation in physical and optical properties (Plate VI-5 to 12). "Normal", hyacinth, and malacon zircon types were classified by colour and birefringence differences. "Normal" zircons are colorless and highly birefringent, hyacinths show coloration (any colour) and high birefringence (at least high second order), and malacons show deep coloration (brown to purple) and first order birefringence. These arbitrary limits of birefringence approximate figures quoted by Poldervaart (1956, p. 548). Zircon varieties were studied in terms of relative and absolute abundance, shape, size, presence or absence of zoning, inclusions, and cores.

"Normal" zircons, hyacinths, and malacons are present in all samples, although sample 60-147-2 shows marked deficiency. Of the three types, hyacinths are most abundant except in samples 60-146-1 and 60-709-2, in which normal zircons are most abundant. Malacons are invariably least abundant.

Rounded crystals predominated in all samples except sample 60-723-8, in which the angularity of grains may be accounted for by small grain size (mainly 0.03 mm), a relationship noted by Hutton (1950, p. 687). Several well-rounded zircon crystals were observed. Rod zircons are distinctively abundant (20 grains or more) in samples 60-146-1 and 60-709-2, their presence being rare or virtually absent in other samples. Square "normal" zircons with rounded corners commonly occurred in sample 60-709-2, giving further indication of its distinctive zircon assemblage. Euhedral crystals were rare to absent.

Length measurements on samples other than 60-723-8 indicate a size range mainly 0.04-0.15 mm, and modal size interval 0.06-0.08 mm.

Prominence of zoned zircons was a striking feature in the samples studied. Zoning was readily recognized by the presence of thread-like concentric lines which were most distinct along the periphery of crystals. A large proportion of hyacinths were zoned, whereas few malacons and "normal" zircons showed zoning.

Mineral and gas inclusions were commonly observed in "normal" zircons and hyacinths, but rarely noted in malacons. Mineral inclusions assumed various shapes and orientations, shapes including rod, acicular, and equidimensional habits, whereas orientation was largely random with occasional elongate inclusions lying parallel to the c-axis of the host zircon crystals. No attempt was made to identify mineral inclusions.

Rounded hyacinth cores surrounded by malacon were observed rarely. In one instance, hyacinth enclosed malacon.

Microfissures commonly occurred subperpendicularly to the c-axis.

Tourmaline

Detrital tourmaline, a common heavy mineral in clastic sediments, was absent in all samples. Harker's (1939, p. 17) statement that detrital tourmaline readily recrystallizes during metamorphism may explain the apparent discrepency, recrystallization perhaps giving rise in part to metamorphic tourmaline observed in four samples.

Metamorphic tourmaline is distinctive, showing euhedral to subhedral prismatic habit, yellow-brown colour with strong pleochroism, and almost invariably possessing abundant inclusions.

Carborundum contamination in some samples was at first misidentified as blue detrital tourmaline; however, direct comparison with mounted carborundum powder verified apprehensions arising from the extreme angularity of grains, faint pleochroism, and higher refractive indices than tourmaline.

Apatite

Abundant apatite occurred, crudely proportional to the quantity of zircons in each sample (fig. 6). Slender to stubby crystals with rounded terminations abound, and angular anhedral grains are common. Rounded terminations of crystals suggest detrital origin, but relative stability data of Poldervaart (1955, p. 438) and common observance of apatite with rounded terminations in igneous and high grade metamorphic rocks favour non-detrital origin.

Titanium Anisotropic Minerals

Titanite was seen occasionally, its presence having been detected in four samples in minor amounts. Identification was commonly rendered difficult by fine-grain size, in which case extremely high relief, deep yellow to brown colour in plane polarized light and under crossed nicols, and incomplete extinction served for identification. The ease with which titanite forms from metamorphic processes (Pettijohn, 1957, p. 518), and blocky shape strongly suggest that these grains are authigenic.

Detrital and metamorphic rutile grains were recognized. The only standard reference rock containing detrital rutile was sample 60-146-1, while metamorphic rutile (Plate VI-3, 4) was identified in samples 60-709-2, 60-717-4, and 60-723-8. The two rutile types were readily distinguished, clastic rutile occurring as well rounded, orange-brown grains with extreme relief, and metamorphic rutile typically occurring as tabular and angular, deep yellow crystals usually with oblique striations and rarely showing lamellar twinning. Chlorite commonly contained minute rutile inclusions of identical habit, thus supporting the metamorphic nature of tabular deep yellow rutile crystals. Harker's (1950, p. 161) statement that decomposition of biotite during dynamic metamorphism gives rise to abundant rutile in the resulting micaceous matrix is strongly supported by samples 60-717-4 and 60-723-8 which are petrographically classified as phyllonite and phyllonitic schist, respectively. Preservation of detrital rutile is accounted for by mineral stability data: Poldervaart (1955, p. 438) rates rutile and

zircon as the two minerals most resistant to intrastratal solution; Pettijohn's (1957, p. 516) Mineral Persistance Chart classifies rutile among the minerals which have remained abundant since at least Huronian time; Harker (1950, p. 52) mentions the persistence of detrital rutile to an advanced grade of metamorphism. The stability of rutile explains its presence as a detrital mineral in the dominantly low grade metamorphic rocks of the Waugh Lake area.

Anatase and brookite are treated together to emphasize their similarities of determinative properties and mode of occurrence. Anatase (Plate VI-1, 2) typically forms blocky cleavage fragments showing striations, yellow to blue colour and extremely high relief. Birefringence is high, but fragments lying on the basal cleavage appear isotropic and give a centred uniaxial interference figure. Brookite tends to occur as striated tabular cleavage fragments showing yellow to orange colour, extremely high relief, high birefringence and dispersion. The high dispersion produces an anomalous interference figure. Harker (1950, p. 53) comments on the presence of authigenic anatase and brookite in rocks of low metamorphic grade.

Micas

Metamorphic micas, consisting of varying proportions of biotite, chlorite, and white mica are abundant in all samples. Their presence largely obscured other heavy minerals, making their exclusion necessary before heavy mineral studies could be carried out. Discussion of micas is reserved for petrography.

Epidote

The abundance of epidote as a metamorphic mineral made it of little use in sedimentary studies. Epidote is discussed in the petrography section.

Opaques

A study of opaques was not undertaken.

Unidentified Mineral

A well-rounded, isotropic mineral with medium relief and pink to pink-brown colour was at first identified as garnet, but the Becke line test (R.I. Aroclor = 1.67) indicated negative relief and thus refractive index significantly less than garnet. Of the common detrital heavy minerals, only allanite in the metamict state approaches the observed properties, but its persistence as a heavy mineral is questionable. One to three grains of this mineral were noted in samples 60-132-1, 60-146-1, and 60-717-4.

Interpretations

The presence of zircon and rutile as the sole remnants of detrital heavy minerals can be explained by several interacting factors. A simple heavy mineral suite would be expected from reworking of pre-existing sedimentary rocks with only the most resistant minerals such as zircon, tourmaline, rutile and garnet persisting. The effect of intrastratal solution in diminishing the heavy mineral suite is conceded

to be crudely proportional to the length of time that the sedimentary rocks have been exposed to its influence. Superimposed on these two effects would be the tendency of metamorphism to destroy and/or recrystallize detrital heavy minerals, notably garnet and tourmaline. Probably, all three factors have been instrumental in producing the heavy mineral suite observed in this study.

Semiquantitative study of zircon types indicated a high proportion of hyacinths, with lesser amounts of "normal" zircons and malacons. Marsden (1955) reported hyacinth-bearing granitic rocks in Michigan, Wisconsin, and Minnesota to be Archean in age, whereas granitic rocks containing malacon and "normal" zircons were established stratigraphically to be consistently younger, ranging from pre-Middle Huronian to pre-Keweenawan. Because of the mixed zircon assemblage of the Waugh Lake metasedimentary rocks, postulation of Archean-type source rocks based on Marsden's findings would be unsatisfactory. However, Folinsbee (1955) described zircon types from igneous rocks and paragneiss in the Lac de Gras map-area of the Yellowknife geologic province. There, hyacinths were found in the sedimentary phase of migmatite and diorite, and "normal" zircons were found in the igneous phase of migmatite and granite. The important aspect indicated by absolute age dating was the equivalence of age (about 2500 million years) of the igneous and derived rocks. Erosion of such terrain would give rise to sediments bearing mixed zircon assemblages, and the proximity of the Tazin-Nonacho metasedimentary band to the Lac de Gras area makes postulation of Yellowknife source rocks feasible.

Summarizing then, heavy mineral studies strongly suggest that the Yellowknife continental nucleus supplied detrital material for sedimentary rocks now represented by the Waugh Lake metasedimentary rocks. Post-depositional history, consisting of intrastratal solution effects, combined with later matamorphic effects, has led to a simple detrital heavy mineral suite.

Provenance as Determined by Quartz and Feldspar Study

Recognition of differences in extinction, inclusions, and nature of grain boundaries permitted Krynine (1940) and Folk (1957) to classify quartz types. Krynine proposed a genetic classification of quartz types. Krynine proposed a genetic classification of quartz types, whereas Folk classified quartz empirically then related the quartz types to the likeliest source rocks. Largely based on Folk's classification, the present study is an attempt to suggest the nature of source rocks from which clastic material giving rise to sedimentary rocks of the Waugh Lake area were derived.

Study of elongation of quartz grains as a clue to provenance, a technique investigated by Bokman (1952), was also attempted to see if results could be correlated with classification of quartz types. Feldspar, as an indicator of provenance and sedimentation history, could not be neglected. Shape of quartz and feldspar grains was noted for its implications of depositional history and maturity.

Fresh samples were required for thin section study. In this respect, thin section 60-709-2 (Plate V-1), a feldspathic wacke which

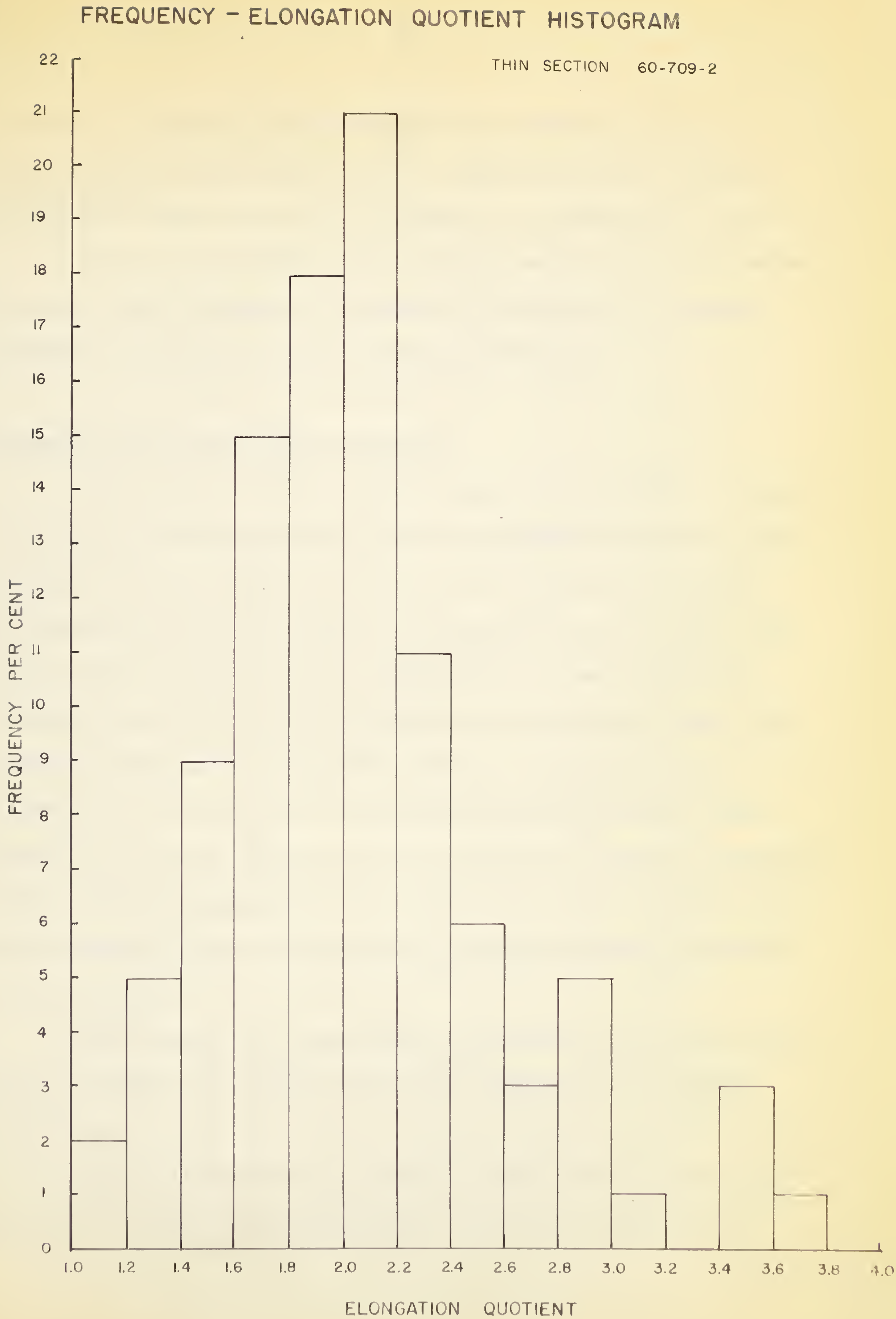
was also used for size analysis, showed optimum preservation of clastic grains, thus proving to be ideal for detailed study. Determination of provenance through the use of a single thin section must be considered hazardous, because of the possibility that the sample chosen may have been selected from an atypical bed. To test this possibility, another thin section, 57-526-1, was chosen for study. Another feldspathic wacke, it showed fresh preservation of clastic nature to a slightly lesser extent than thin section 60-709-2. Slight to moderate recrystallization of clastic grains was detected in thin section 57-526-1, thus measurements of maximum and minimum diameters were not attempted.

Procedure

Random selection of grains was achieved by using a mechanical stage mounted on the petrographic microscope. Traverses were spaced 0.5 millimetre apart, with movement of 0.5 millimetre increments along traverses. Sand-sized (greater than 0.062 millimetre) grains of quartz and feldspar that intersected the mid-point of the micrometer scale were studied in detail.

Quartz grains were studied in the following respects: measurement of maximum and minimum diameters were carried out under medium power; roundness was visually estimated with a roundness chart (AGI 7); inclusion type was studied under high power; and extinction type was determined using medium power. Measurement of grain diameters permitted calculation of elongation quotient (maximum diameter/minimum diameter) for each grain. Elongation quotients listed in Appendix A

Figure 7


FREQUENCY - ELONGATION QUOTIENT HISTOGRAM
THIN SECTION 60-709-2
FREQUENCY PER CENT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
ELONGATION QUOTIENT

were used to construct a histogram (fig. 7). Following empirical classification of quartz types, genetic classification was attempted, the results of which are listed in Appendix A and summarized in Table 8.

The study of feldspar grains involved measurement of the maximum diameter, visual estimation of roundness, determination of feldspar varieties, and categorization of feldspar alteration.

Discussion and Interpretation of Results

Quartz grains showed a marked tendency to be elongated. Inspection of the frequency-elongation quotient histogram indicates the modal elongation quotient interval to be 2.0 to 2.2; 65 per cent of grains have elongation quotients falling in the range 1.6 to 2.4, 19 per cent greater than 2.4, and 16 per cent less than 1.6. Thus, elongations indicate a source area consisting dominantly of metamorphic rocks, with relatively minor amounts of granitoid rocks. In terms of genetic classification, injected and recrystallized metamorphic quartz types dominate, with lesser amounts of plutonic quartz and pressure metamorphic quartz. Pressure metamorphic quartz tends to be acutely stretched, thus grains showing elongations greater than 2.4 were arbitrarily classified in this category.

Quartz grains are predominantly very angular to subangular, the presence of some well-rounded grains being suggestive of multicycle derivation.

Study of inclusions and extinction types of quartz grains have given rise to speculative determination and relative quantities of

Table 8

Source Rocks Determined by Study of Quartz Types

Slide Number	Source Rock	Percentage
60-709-2*	Granite***	19
	Granite Gneiss	44
	Recrystallized Metamorphic****	15
	Pressure Metamorphic*****	15
	Hydrothermal veins	7
		100 %
57-526-1**	Granite	16
	Granite Gneiss	38
	Recrystallized Metamorphic	12
	Pressure Metamorphic	30
	Hydrothermal veins	4
		100 %

* 100 quartz grains studied.

** 50 quartz grains studied.

*** Quartz grains from granites usually contain no mineral inclusions, whereas quartz grains from granite gneiss commonly contain inclusions.

**** Rock types include metaquartzite, injected schist and gneiss. Distinction of recrystallized metamorphic quartz from granite gneiss quartz was considered to be impossible in the absence of composite grains; single grains possessing characteristics of recrystallized metamorphic quartz were arbitrarily grouped in the granite gneiss category.

***** Rock types include sheared metaquartzite, schist, and gneiss.

source rocks (Table 8). Comparison of results for thin sections 60-709-2 and 57-526-1 indicate close agreement in the relative amounts of each source rock except pressure metamorphic which was twice as abundant in 57-526-1 than 60-709-2. The results are suggestive of high grade gneissic source rocks interspersed with less granitized gneiss, schist, meta-quartzite and their sheared equivalents. Massive granitic rocks formed a significant part of the source area. The source area pictured here closely resembles much of the Archean-type gneissic terrain mapped in adjacent areas.

Feldspar studies of 50 sand-sized grains from thin section 60-709-2 indicate a majority of subangular to subrounded grains, about equal amounts of twinned (29 grains) and untwinned (21 grains) plagioclase, displaying variable degrees of alteration. It is interesting to note that of 16 very angular to angular grains, 12 were twinned plagioclase, and of 17 unaltered feldspars, 16 were twinned plagioclase; the likeliest explanation of these two relationsips is that many of the twinned plagioclase grains were derived from source rocks relatively closer to the basin of deposition than untwinned feldspars. Survival of plagioclase grains may be attributed to rapid erosion and transportation from uplifted terrain, followed by rapid burial brought about by "dumping".

CHAPTER V

METAMORPHISM

General Statement

The most striking feature of the Waugh Lake area is the slightly metamorphosed appearance of the metasedimentary rocks, a feature in direct contrast with the granitoid and gneissic rocks of the surrounding terrain. However, metamorphic effects are strongly evident throughout the metasedimentary band.

Regional metamorphism has recrystallized sedimentary rocks, giving rise to hard, dense rocks in which primary sedimentary features are largely destroyed except in an elongate "core" about one mile wide and three miles long, extending along Waugh Lake.

Dynamic metamorphism has caused considerable disruption of the metasedimentary rocks. Major folds in the central part of the map-area are represented on the geological map. On outcrop scale, minor folds and contorted bedding are common structural features in the central area, whereas metasedimentary rocks away from the central area tend to be massive and structureless. Major faults are defined along the eastern margin, in the central area, and near the western margin of the metasedimentary band. Mylonite was commonly observed where faults were recognized, but the central fault zone showed formation of crush conglomerate "pebbles" in phyllonite. Examination of thin sections shows that shearing was largely confined to micaceous, fissile rocks where available in an area subjected to strong shear movement.

Abundant tourmaline in metasedimentary rocks (Plate II-3) near the amphibolite mass at the southeast corner of Waugh Lake suggests that boron metasomatism was associated with igneous activity. Alternatively, heat from the cooling mass may have mobilized boron contained in the clastic rocks, resulting in tourmaline concentrations in that vicinity.

Laboratory study of rocks from the large southern basic rock body was made in an attempt to describe the rock types and grade of metamorphism within the body.

Grade of metamorphism of the metasedimentary rocks is indicated by a study of plagioclase feldspars.

Basic Rock Problem

Statement of Problem

The difficulty encountered in distinguishing fine-grained basic to intermediate lavas from interlayered metasedimentary rocks in the field was mentioned in chapter III. The present study is an attempt to separate the two genetic rock types by laboratory analysis, and indicate the relative amounts present. The large bulbous basic body occupying the southwest quarter of the map-area is of primary concern; the large basic body in the north-central region presented fewer uncertainties during the course of mapping, thus laboratory study of this body is neglected.

Determination of Parent Rocks by Facies Classification

Fyfe, Turner and Verhoogen's (1958) discussion of mineral assemblages characteristic of metamorphic rocks derived from the main

chemical rock classes gave rise to construction of Table 9. Using this table, mineral assemblages of 27 thin sections from the large southern basic body were matched with the appropriate subfacies and chemical rock class. Results are presented in Table 10.

Two difficulties arose during facies classification. (1) The mineral assemblages of thin sections 58-20-1 and 58-545-3 were typical of basic rocks in the lower almandine-amphibolite facies, except for the presence of abundant chlorite; the problem was resolved by attributing formation of chlorite to hydrothermal alteration of biotite and hornblende. (2) Thin sections 57-197-1_{III}, 58-19-8, and 58-19-9 contained significant quantities of carbonate (7 per cent, 3 per cent, and 5 per cent respectively) permitting interpretation that they had been derived from basic rocks or from impure calcareous rocks. However, in the absence of recognizable calcareous rocks in the field, the samples were classified as basic in nature.

Discussion of Results

Of the 27 thin sections investigated, 18 possessed mineral assemblages diagnostic of basic parent rocks, whereas 5 were characteristic of pelitic rocks, and 4 were characteristic of quartzo-feldspathic rocks. The results indicate that the southern basic body consists dominantly of basic rocks intercalated with secondary amounts of pelitic and quartzo-feldspathic rocks. However, this interpretation is subject to revision pending a statistically controlled grid-type sampling program in the field.

Grade of metamorphism ranges from middle greenschist facies (quartz-albite-epidote-biotite subfacies) to lower almandine-amphibolite facies

Table 9

Typical Mineral Assemblages Associated with the Common Chemical Rock Classes

CHEMICAL ROCK CLASS	METAMORPHIC GRADE: GREENSCHIST FACIES (GSF) I. q-ab-mu-chl SF	GREENSCHIST FACIES (GSF) II. q-ab-ep-bi SF	GREENSCHIST FACIES (GSF) III. q-ab-ep-alm SF	ALMANDINE-AMPHIBOLITE FACIES (AAF) I. staur-q SF	ALMANDINE-AMPHIBOLITE FACIES (AAF) II. ky-mu-q SF	ALMANDINE-AMPHIBOLITE FACIES (AAF) III. sill-alm SF
PELITIC (P)	1. q-mu-chl-ab (ep-T) (chlor zone)	1. bi-mu-q(Ab-ep) 2. mu-bi-chl'd-q (ab-ep) 3. mu-bi-chl'd-ky -q 4. bi-chl'd-chl-q(ab-ep) 5. chl-bi-q(ab-ep) (biotite zone)	1. mu-bi-alm-q (ab-ep) 2. mu-chl'd-alm-q (ab-ep) 3. mu-chl'd-q (bi-ep-ab) 4. mu-chl'd-ky-q (low alm zone)	1. q-ky-staur-mu-pl-(bi) 2. q-staur-alm-mu-bi-pl 3. q-alm-mu-bi-pl-(ep) 4. q-mu-bi-micro -pl (staur zone)	1. q-ky-mu-alm-pl(bi) 2. q-alm-mu-bi-pl(ep) 3. q-mu-bi- -micro-pl (ky zone)	1. q-micro-sill-alm(pl-bi) (sill zone)
BASIC (B)	1. ab-ep-chl-act-S(q) 2. ab-ep-chl-S-(q) 3. ab-ep-chl-ct-S(q-act)	1. ab-ep-act-chl-S(q-bi) 2. ab-ep-chl-(q-bi) 3. ab-ep-act(q-micro-bi)	1. hbl-ab-ep-alm (bi-q) 2. hbl-ab-ep-bi (q) 3. hbl-ab-ep(q)	1. hbl-pl-alm-ep(q-bi) 2. hbl-pl-ep(q-bi)	1. hbl-pl-bi(q) 2. hbl-pl-gar (q) 3. hbl-pl	1. hbl-pl(di-q) 2. hbl-pl(alm-q)
QTZO-FP'IC(QF)	1. q-ab-mu(ep)	1. q-ab-micro (bi-mu-ep) 2. q-ab-micro-bi(ep)	1. q-micro-ab-ep-bi-mu 2. q-micro-ab-ep-bi	1. q-micro-pl-bi-mu(ep)		1. q-micro-sill- -alm(pl-bi)
CALC-SILI-CATE(CS)	1. ct-ep-trem-q	1. ct-ep-trem(q)	1. ct-ep-trem-q	1. ct-di-ep(pl) (q-micro) 2. di-hbl-ep (pl)(q-micro)		1. an-di-gar-q 2. ct-gar-di-q 3. an-di-hbl-q

Table 10 Data from Study of Southern Basic Body

Thin Section Number	Mineralogy												Facies Classification and Chemical Rock Class
	ct	q	Feldspars			ep	mu	chl	bi	hbl	Rock frag.	Access.	
			Neg. R.I.	Pos. R.I.	twn. pl								
57-196-11_{II}	tr	50	10	-	30	5	2	-	5	-	qtze	S, A	AAF-I, QF-1
57-196-11_{III}	tr	10	10	-	tr	15	-	-	35	30	-	A	GSF-III, B-2
57-197-1_{I}	-	10	tr	-	40	8	-	-	7	25	-	S	AAF-I, B-2
57-197-1_{II}	-	20	5	25	5	5	-	2	40	-	-	A	GSF-II, P-5
57-197-1_{III}	7	15	3	-	30	7	-	-	25	15	-	A, M	AAF-I, B-2
57-527-6	-	40	8	-	20	-	10	tr	15	-	qtze	A	AAF-I, P-4
57-528-1	-	25	5	-	25	10	-	-	15	20	-	S, A	AAF-I, B-2
57-528-2	-	40	20	-	30	1	1	tr	7	-	-	S, A	AAF-I, QF-1
57-528-3	tr	40	10	-	30 (Ab)	7	-	-	10	-	-	S, A	GSF-III, QF-2
58-19-5	-	50	-	15	-	7	5	tr	15	-	qtze	A, M, L	GSF-II, P-1
58-19-6	-	20	5	-	40	5	3	2	5	-	-	S, A	AAF-I, QF-1
58-19-7	-	15	5	-	30	8	-	tr	20	15	-	-	AAF-I, B-2
58-19-8	3	30	5	25	15	5	-	2	10	7	-	A	GSF-II, B-2
58-19-9	5	20	5	20	15	10	-	10	15	3	-	S, P, T	GSF-II, B-2

Visual estimates in per cent

Table 10 Data from Study of Southern Basic Body

Thin Section Number	Mineralogy												Facies Classification and Chemical Rock Class
			Feldspars										
	ct	q	Neg. R.I.	Pos. R.I.	twn. pl	ep	mu	chl	bi	hbl	Rock Frag.	Access.	
58-20-1	-	15	5	20	15	20	-	15	8	7	-	S	AAF-I, B-2
58-20-2	-	35	5	20	-	5	-	20	15	-	-	A, P	GSF-II, P-5
58-21-2	-	40	5	-	-	8	-	-	35	10	-	M	GSF-II, P-5
58-544-1	1	20	3	10	40	7	-	tr	15	3	-	S, A, P	AAF-I, B-2
58-545-1	-	5	5	-	-	10	-	tr	15	65	-	M	GSF-III, B-2
58-545-2	-	20	-	25	15	12	-	-	25	3	-	S	AAF-I, B-2
58-545-3	-	15	2	15	15	10	-	20	10	15	-	-	AAF-I, B-2
58-546-1	-	25	-	30	-	5	-	2	25	15	-	A	GSF-III, B-2
58-548-1	-	25	3	35	15	2	-	3	10	7	-	A, M, P	GSF-III, B-2
58-549-1	1	20	3	10	20	10	-	-	15	25	-	S	AAF-I, B-2
58-549-2	-	15	10	10	-	20	-	-	25	20	-	A	GSF-III, B-2
58-1026-2	-	20	20	15	5	10	-	-	20	10	-	S, A	GSF-III, B-2
60-711-5	-	10	5	5	35	10	-	-	25	15	-	S	AAF-I, B-2

Visual estimates in per cent

LEGEND FOR TABLES 9 AND 10

Mineralogy

A	apatite	hbl	hornblende
ab	albite	ky	kyanite
Access.	accessory minerals	M	magnetite
act	actinolite	micro	microcline
alm	almandine	mu	muscovite
an	anorthite	P	pyrite
bi	biotite	pl	plagioclase
chl	chlorite	q	quartz
chl'd	chloritoid	S	sphene
ct	calcite	sill	sillimanite
di	diopside	staur	staurolite
ep	epidote	T	tourmaline
gar	garnet	trem	tremolite

Chemical Rock Classes

B Basic - derivatives of basic and semibasic igneous rocks tuffs, and some tuffaceous sedimentary rocks.

CS Calc-silicate - derivatives of impure limestones, dolomites, marls.

P Pelitic - derivatives of aluminous sedimentary rocks.

QF Quartzo-feldspathic - derivatives of sandstones and acid igneous rocks.

Metamorphic Grade

F Facies:

- AAF Almandine-Amphibolite Facies
- GSF Greenschist Facies

SF Subfacies:

- I lower
- II middle
- III upper

Miscellaneous

Frag.	fragment
Neg.	negative
Pos.	positive
R.I.	refractive index
twn.	twinned

(staurolite-quartz subfacies), but is dominantly transitional from upper greenschist to lower almandine-amphibolite grade.

Grade of Metamorphism

Determination of plagioclase composition as an indication of metamorphic grade of metasedimentary rocks was attempted, using the Michel Levy method on thin sections mounted on the universal stage. The rarity of twinned plagioclase limited this part of the programme since only 6 thin sections were found suitable for study (see Table 11). Feldspathic arenite and feldspathic wacke samples used in this study, give an almost complete east-west section of the metasedimentary band.

Table 11

Plagioclase Composition* of Selected Metasedimentary Rocks

Sample Number	Petrographic Classification	Plagioclase Composition
60-143-4	Feldspathic Arenite	An_{6-10}
60-147-6	Feldspathic Arenite	An_8
60-711-1	Feldspathic Wacke	An_8
60-712-7	Feldspathic Wacke	An_8
60-716-3	Tuffaceous Metasedimentary Rock	An_{47}
60-137-4	Tuffaceous Metasedimentary Rock	An_{49-55}

* 3 plagioclase grains from each slide selected for composition study.

Interpretation of Results

Composition of plagioclases from feldspathic arenite and feldspathic wacke thin sections indicate uniform and low metamorphic grade exists across the metasedimentary band. In each thin section, the feldspars are calcic albite, which suggests that these rocks belong in the greenschist facies of regional metamorphism. Alternatively, the plagioclases could have been derived from albite-rich source rocks, and the original composition of plagioclases has been virtually unaffected by metamorphism.

Comparison of the mineralogy of each thin section with Table 9 (Typical Mineral Assemblages Associated with the Common Chemical Rock Classes) establishes metamorphic grade as quartz-albite-muscovite-chlorite subfacies to quartz-albite-epidote-biotite subfacies of the greenschist facies.

Composition of plagioclases from tuffaceous metasedimentary rocks (An_{47-55}) indicate that feldspars were derived from basic to intermediate volcanic parent material (An_{41-60}).

CHAPTER VI

SUMMARY AND CONCLUSIONS

General Statement

Mapping of Precambrian terrain in northeastern Alberta defined a triangular-shaped band of slightly metamorphosed Tazin metasedimentary rocks which form a part of the Tazin-Nonacho metasedimentary band extending from south of the east arm of Great Slave Lake to Lake Athabasca. In the Waugh Lake area, the metasedimentary rocks are believed to be folded and/or faulted into the underlying granite gneiss complex. The metasedimentary band consists dominantly of fine-grained arenites, wackes, and schists, with lenses of conglomeratic rocks and masses of volcanic rocks, whereas granitoid and gneissic rocks surround the metasedimentary complex. Intruding the band are several granite plugs and a basic dyke. The fresh appearance of the metasedimentary rocks, and the numerous lithologic types make the area suitable for detailed study.

Metamorphism

Various metamorphic effects are notable in the area. Regional metamorphic grade is uniformly low in the metasedimentary rocks, mainly in the quartz-albite-epidote-biotite subfacies of the greenschist facies, which probably accounts for the preservation of primary sedimentary structures. However, a large basic body in the southwest quarter of the map-area is higher in metamorphic grade, mainly in the quartz-albite-epidote-almandine subfacies of the greenschist facies, and the staurolite-quartz subfacies

of the almandine-amphibolite facies. In general, the basic body shows metamorphic recrystallization and a metamorphic mineral assemblage characteristic of the upper greenschist and lower almandine-amphibolite facies. However, a quartz basalt sample from the centre of the basic body shows relic igneous flow texture.

Effects of dynamic metamorphism are common throughout the area, the most striking evidence being the occurrence of crush conglomerates and mylonites. The problem of classifying a sericitic rock containing abundant rounded rock fragments as sheared conglomerate or tectonic conglomerate remains unsolved.

Boron metasomatism is believed to be responsible for abnormal concentrations of tourmaline in metasedimentary rocks surrounding the amphibolite plug at the southeast corner of Waugh Lake.

A special study, not done by the writer, has shown that porphyroblastic microgranodiorite (biotite granite C) in the southern part of the map-area was derived by granitization of basic rocks and/or pelitic sedimentary rocks of the Waugh Lake band.

Sedimentation

Sedimentation studies are limited by the state of preservation of textures and recrystallization of clastic grains, but to provide information on the Tazin rocks, a study of the metasedimentary rocks, using adaptations of normal sedimentation techniques, was attempted.

The technique of size analysis by thin section is questionable, especially where comparison of samples is made with sieve-size analyses, and where thin section analyses of different operators are compared. In the present study, no attempt is made to compare results with similar studies. Rather, the data obtained are used to describe characteristics

of a wacke, which is shown to have a unimodal, normal symmetrical size distribution, poor sorting, and a modal size class interval of 0.044-0.053 millimetre.

A stable suite of detrital heavy minerals, consisting of rutile and zircon, is found in the metasedimentary rocks. Metamorphic heavy minerals include epidote, biotite, chlorite, tourmaline, apatite, titanite, rutile, anatase, and brookite. The paucity of detrital heavy minerals may be explained by reworking of sediments, intrastratal solution, and metamorphic recrystallization. Reworking of sediments has occurred, as shown by the presence of some well-rounded quartz grains. Recrystallization of some heavies is postulated because of the presence of metamorphic apatite and tourmaline, and absence of normally ubiquitous detrital apatite and tourmaline. However, intrastratal solution has probably been most instrumental in reducing the heavy mineral suite. Nevertheless, the abundance of zircons in all samples permitted detailed studies to be carried out. A mixed zircon assemblage occurred in each sample, with a relative high proportion of hyacinths over "normal" zircons and malacons. This zircon assemblage would be expected in sediments derived from Archean rocks of the Yellowknife geologic province, as indicated by zircon studies carried out in the Lac de Gras map-area by Folinsbee (1955).

The study of source rocks was attempted by analysing quartz and feldspar grains from feldspathic wacke thin sections which showed good clastic texture and minimum effects of shearing and recrystallization of sand-sized grains. By studying elongation, inclusions, and extinction types of quartz grains, it was possible to postulate a dominantly metamorphic source area consisting of high grade gneissic rocks with smaller amounts of granitoid rocks and low grade gneiss, schist, quartzite, and

their sheared equivalents. Source rocks postulated by study of quartz types closely ressemble rocks of the Archean-type gneissic terrain in adjacent areas. The presence of rare well-rounded quartz grains is suggestive of some multicycle source. Feldspar study shows the absence of potassium feldspar, indicating that source rocks were probably low in potassium feldspar. Furthermore, it is shown that most of the very angular to angular feldspars and most of the unaltered feldspars are twinned plagioclases, which indicates that many of the twinned plagioclases were eroded from an area of high relief and "dumped" into a nearby basin of deposition.

Inferred Environment of Deposition

The association of impure arenites, wackes, finely laminated siltstone, lavas, tuffs, and in a negative sense, absence of calcareous rocks and "clean" quartz arenites resembles Pettijohn's (1957, p. 615-618) description of "the graywacke suite", typical of a deep-water environment of sedimentation. If the conglomerate-like rocks in the west half of the map-area are true conglomerates, their presence and stratigraphic position may be explained by placing them near the base or alternatively, near the top of the stratigraphic section. In the former case, the "conglomerates" may have been deposited among the initial sediments in a sinking depositional trough, whereas in the latter case, the "conglomerates" may have been deposited in an almost silted-up geosyncline.

Graded bedding of wackes and absence of crossbedding substantiates postulation of deposition in a geosynclinal environment.

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Appendix A

Data from Study of Quartz and Feldspar

Data from Study of Quartz Types

Thin Section 60-709-2

Grain Number	Long Diameter "a"	Short Diameter "b"	Elongation "a"/"b"	Roundness	Inclusion Type (Folk)	Extinction Type (Folk)	Classification (Folk, Krynine)
1	0.14 mm	0.10mm	1.5	subang.	c	2	GN
2	0.13	0.06	2.0	subr.	d	1	GR
3	0.10	0.06	1.7	subang.	a	2	HV
4	0.14	0.08	1.8	subang.	c	5	RM
5	0.14	0.06	2.6	subang.	c	5	RM
6	0.19	0.08	2.4	ang.	d	5	RM
7	0.10	0.06	1.7	subang.	c	1	GN
8	0.13	0.06	2.0	ang.	d	1	GR
9	0.19	0.10	2.0	ang.	c	5	RM
10	0.16	0.06	2.9	ang.	c	1	GN
11	0.11	0.06	1.8	ang.	c	2	GN
12	0.12	0.06	2.1	subr.	d	1	GR
13	0.10	0.04	2.4	ang.	d	1	GR
14	0.21	0.10	2.2	ang.	c	1	GN
15	0.19	0.10	1.9	ang.	d	5	RM
16	0.21	0.10	2.2	v. ang.	d	3	PM
17	0.10	0.05	2.0	ang.	c	1	GN
18	0.22	0.17	1.3	ang.	d	1	GR
19	0.11	0.06	1.8	ang.	c	2	GN
20	0.16	0.06	2.9	ang.	c	4	HV
21	0.10	0.07	1.3	subr.	d	3	PM
22	0.14	0.08	1.7	subang.	d	5	RM
23	0.13	0.08	1.5	subr.	c	2	GN
24	0.08	0.03	2.5	and.	c	2	GN
25	0.17	0.07	2.5	v. ang.	c	5	RM
26	0.11	0.06	1.8	v. ang.	c	2	GN
27	0.13	0.07	1.8	ang.	d	1	GR
28	0.19	0.09	2.1	ang.	d	2	GR
29	0.15	0.13	1.2	ang.	c	5	RM
30	0.13	0.08	1.5	ang.	c	5	RM
31	0.14	0.06	2.3	subr.	c	2	GN
32	0.11	0.07	1.6	subang.	d	1	GR
33	0.17	0.06	2.8	v. ang.	d	3	PM

Data from Study of Quartz Types

Thin Section
60-709-2 (continued)

Grain Number	Long Diameter "a"	Short Diameter "b"	Elongation "a"/"b"	Roundness	Inclusion Type (Folk)	Extinction Type (Folk)	Classification (Folk, Krynine)
34	0.14 mm	0.06 mm	2.1	v. ang.	c	2	GN
35	0.14	0.08	1.7	v. ang.	d	5	RM
36	0.13	0.08	1.6	ang.	c	3	PM
37	0.11	0.06	1.6	ang.	d	2	GR
38	0.19	0.10	2.0	subang.	c	3	PM
39	0.11	0.06	1.7	v. ang.	c	5	RM
40	0.13	0.07	1.9	v. ang.	d	2	GR
41	0.13	0.12	1.1	subang.	a	5	RM
42	0.15	0.08	1.8	v. ang.	c	2	GN
43	0.13	0.04	3.4	ang.	c	1	GN
44	0.14	0.08	1.7	v. ang.	a	1	HV
45	0.19	0.13	1.5	v. ang.	c	3	PM
46	0.13	0.08	1.8	ang.	c	2	GN
47	0.13	0.09	1.5	ang.	a	2	GR
48	0.13	0.07	1.8	v. ang.	d	5	RM
49	0.14	0.05	3.0	v. ang.	c	6	PM
50	0.14	0.07	2.0	v. ang.	c	1	GN
51	0.14	0.07	2.1	v. ang.	c	2	GN
52	0.13	0.06	2.1	v. ang.	d	3	PM
53	0.13	0.04	3.5	v. ang.	c	2	GN
54	0.19	0.08	2.4	subang.	c	1	GN
55	0.20	0.11	1.8	ang.	c	3	PM
56	0.15	0.07	2.3	subang.	c	2	GN
57	0.16	0.12	1.4	v. ang.	c	6	PM
58	0.27	0.11	2.4	v. ang.	c	6	PM
59	0.23	0.06	3.6	v. ang.	c	1	GN
60	0.08	0.06	1.3	subang.	c	2	GN
61	0.16	0.06	2.9	ang.	c	2	GN
62	0.10	0.05	2.0	subr.	c	2	GN
63	0.14	0.07	2.1	v. ang.	c	3	PM
64	0.20	0.07	2.8	ang.	c	2	GN
65	0.19	0.06	3.5	ang.	c	1	GN
66	0.11	0.06	1.8	subr.	d	1	GR
67	0.13	0.08	1.5	v. ang.	a	1	HV

Data from Study of Quartz Types

Thin Section
60-709-2 (continued)

Grain Number	Long Diameter "a"	Short Diameter "b"	Elongation "a"/"b"	Roundness	Inclusion Type (Folk)	Extinction Type (Folk)	Classification (Folk, Krynine)
68	0.13 mm	0.09 mm	1.5	subang.	c	1	GN
69	0.11	0.05	2.2	subang.	b	2	GR
70	0.13	0.06	2.3	v. ang.	d	1	GR
71	0.11	0.06	1.7	v. ang.	c	2	GN
72	0.13	0.08	1.6	v. ang.	a	4	HV
73	0.12	0.06	2.1	subang.	a	2	HV
74	0.11	0.06	1.8	v. ang.	d	2	GR
75	0.17	0.08	2.1	ang.	c	2	GN
76	0.26	0.12	2.2	subang.	c	1	GN
77	0.17	0.10	1.7	v. ang.	c	2	GN
78	0.22	0.10	2.3	v. ang.	c	1	GN
79	0.14	0.11	1.3	subang.	c	5	RM
80	0.11	0.05	2.2	subr.	d	1	GR
81	0.23	0.11	2.0	subr.	c	2	GN
82	0.13	0.06	2.0	subang.	a	2	HV
83	0.14	0.07	2.0	ang.	c	1	GN
84	0.13	0.08	1.7	subang.	c	2	GN
85	0.17	0.08	2.1	subang.	c	2	GN
86	0.11	0.06	1.8	ang.	c	2	GN
87	0.14	0.08	1.8	ang.	c	1	GN
88	0.17	0.08	2.0	v. ang.	c	1	GN
89	0.16	0.06	2.6	ang.	c	1	GN
90	0.13	0.09	1.5	ang.	c	1	GN
91	0.16	0.08	2.0	ang.	c	5	RM
92	0.15	0.10	1.6	subang.	c	2	GN
93	0.08	0.07	1.1	ang.	c	6	PM
94	0.13	0.06	2.2	w. rounded	d	2	GR
95	0.11	0.06	1.8	w. rounded	c	1	GN
96	0.21	0.10	2.2	subang.	c	3	PM
97	0.10	0.06	1.9	rounded	d	2	GR
98	0.12	0.06	1.9	subr.	d	3	PM
99	0.11	0.04	2.6	subang.	d	1	GR
100	0.19	0.11	1.7	subr.	c	2	GN

Thin Section 57-526-1

Data from Study of Quartz Types

Grain Number	Inclusion Type (Folk)	Extinction Type (Folk)	Classification (Folk, Krynine)
1	c	2	GN
2	c	5	RM
3	d	2	GN
4	d	1	GR
5	d	1	GR
6	d	5	RM
7	d	2	GN
8	d	2	GN
9	d	1	GR
10	d	2	GN
11	c	3	PM
12	c	1	RM
13	d	1	GR
14	d	3	PM
15	c	5	RM
16	d	2	GN
17	c	2	GN
18	d	3	PM
19	c	5	PM
20	c	5	PM
21	c	2	GN
22	a	2	HV
23	c	2	GN
24	d	2	GN
25	d	3	PM
26	d	2	GN
27	c	6	PM
28	c	2	GN
29	d	6	PM
30	d	5	RM
31	c	3	PM
32	c	6	PM
33	d	1	GR
34	d	3	PM
35	c	2	GN
36	c	2	GN
37	c	6	PM
38	d	3	PM
39	d	3	PM
40	d	2	GN
41	c	2	GN
42	d	2	GN
43	c	2	GR
44	c	3	PM
45	a	6	HV
46	c	1	GR
47	d	2	GN
48	a	5	RM
49	c	2	GN
50	d	1	GR

Thin Section
60-709-2

Feldspar Study

Grain Number	Maximum Diameter	Roundness	Feldspar Variety	Alteration
1	0.14 mm	angular	Twinned Plagioclase	Clear, sericitic
2	0.14	subrounded	untwinned	cloudy
3	0.10	subangular	untwinned	cloudy
4	0.13	subrounded	untwinned	cloudy
5	0.08	subangular	twinned	clear
6	0.29	subrounded	twinned	clear, sericitic
7	0.17	subrounded	untwinned	cloudy
8	0.14	subangular	untwinned	clear, sericitic
9	0.11	angular	untwinned	clear, micaceous
10	0.10	subangular	twinned	clear, sericitic
11	0.21	subrounded	untwinned	cloudy, micaceous
12	0.10	subangular	untwinned	cloudy, micaceous
13	0.21	subrounded	twinned	cloudy
14	0.08	angular	twinned	cloudy
15	0.11	subrounded	twinned	clear
16	0.13	angular	twinned	cloudy, micaceous
17	0.11	angular	untwinned	cloudy
18	0.14	subangular	twinned	clear
19	0.16	subangular	twinned	clear
20	0.13	angular	twinned	clear
21	0.11	subangular	twinned	cloudy
22	0.17	subrounded	untwinned	cloudy
23	0.14	subangular	untwinned	cloudy
24	0.17	angular	twinned	clear
25	0.16	subangular	untwinned	cloudy
26	0.11	subangular	twinned	clear
27	0.19	subrounded	untwinned	cloudy
28	0.20	angular	untwinned	cloudy
29	0.21	subrounded	untwinned	cloudy
30	0.10	subangular	twinned	cloudy
31	0.13	subrounded	untwinned	sericitic
32	0.17	angular	twinned	clear
33	0.10	subangular	twinned	clear
34	0.16	subangular	untwinned	cloudy
35	0.12	subangular	twinned	clear
36	0.16	subangular	untwinned	cloudy
37	0.18	subrounded	untwinned	cloudy, sericitic
38	0.08	very angular	twinned	clear
39	0.15	angular	twinned	clear, sericitic
40	0.13	angular	twinned	cloudy
41	0.11	subangular	twinned	clear
42	0.10	subrounded	twinned	clear
43	0.11	angular	untwinned	cloudy
44	0.09	subrounded	twinned	cloudy
45	0.17	subangular	untwinned	cloudy, sericitic
46	0.13	angular	twinned	clear
47	0.15	angular	twinned	clear
48	0.11	angular	twinned	cloudy
49	0.19	subangular	twinned	cloudy, sericitic
50	0.13	subrounded	twinned	cloudy, sericitic

LEGEND

(For Study of Quartz Types)

Extinction Types:

1	Single grain; straight extinction.
2	Single grain; slightly undulose extinction.
3	Single grain; strongly undulose extinction.
4	Semicomposite grain; straight to slightly undulose extinction; grains have very close optical orientation.
5	Composite grain; straight to slightly undulose extinction; grains have widely differing optical orientation; normal (not crenulated) grain boundaries.
6	Composite grain; strongly undulose extinction; crenulated borders usually; elongate grains.

Inclusion Types:

a	Abundant vacuoles.
b	Rutile needles.
c	Microlites.
d	Few vacuoles, no microlites.

Classification:

GR	Granite.
GN	Granite Gneiss.
RM	Recrystallized metamorphic rocks.
PM	Pressure metamorphic rocks: Schists, gneisses, metaquartzites.
HV	Hydrothermal veins.

Roundness abbreviations:

w. rounded	well rounded
subr.	subrounded
subang.	subangular
and.	angular
v. ang.	very angular

PLATE I

FIELD PHOTOGRAPHS

1. Slightly metamorphosed sedimentary rocks, showing vertical foliation. East shore, Waugh Lake.

2. Crush conglomerate in phyllonitic biotite schist with steeply dipping foliation. North of Waugh Lake.

3. Amphibolite knoll. Southeast shore of Waugh Lake.

PLATE I

1

2

3

PLATE II

FIELD PHOTOGRAPHS

1. Four inches thick graded beds in quartzite.

2. Graded beds showing development of fracture cleavage. East shore of Waugh Lake.

3. Tourmaline-rich bands and veins in metasedimentary rocks. Southeast corner of Waugh Lake.

PLATE II

1

2

3

PLATE III

FIELD PHOTOGRAPHS

1. Typical contorted beds in siliceous biotite schist. Shoreline, Waugh Lake.

2. Granitic cobbles in sericitic, porphyroclastic phyllonite. West of Waugh Lake

3. Ten inch granitic boulder in sericitic porphyroclastic phyllonite. Note shears and granulation along the periphery of the boulder.

PLATE III

1

2

3

PLATE IV

PHOTOGRAPHS OF POLISHED ROCK SLABS

Note: Length of ruler is 2 inches

1. Pebble of vein quartz in a matrix of fractured and sheared impure quartzite. Sample 60-129-4.

2. Recrystallized mylonite, showing stretched pods of epidote and feldspar. Sample 60-135-1.

3. Fine-grained phase of siliceous conglomerate. Good bedding in silty matrix. Sample 60-706-2.

4. Sericitic, porphyroclastic phyllonite with angular to rounded rock fragments. The dark-coloured angular fragments are low grade metamorphic rock fragments. Sample 60-132-1.

5. Finely laminated quartzose siltstone. Sample 60-147-2.

6. Apparent crossbedding in sample 60-147-2. Rock slab cut along bottom edge of sample as oriented in photograph 5.

PLATE IV

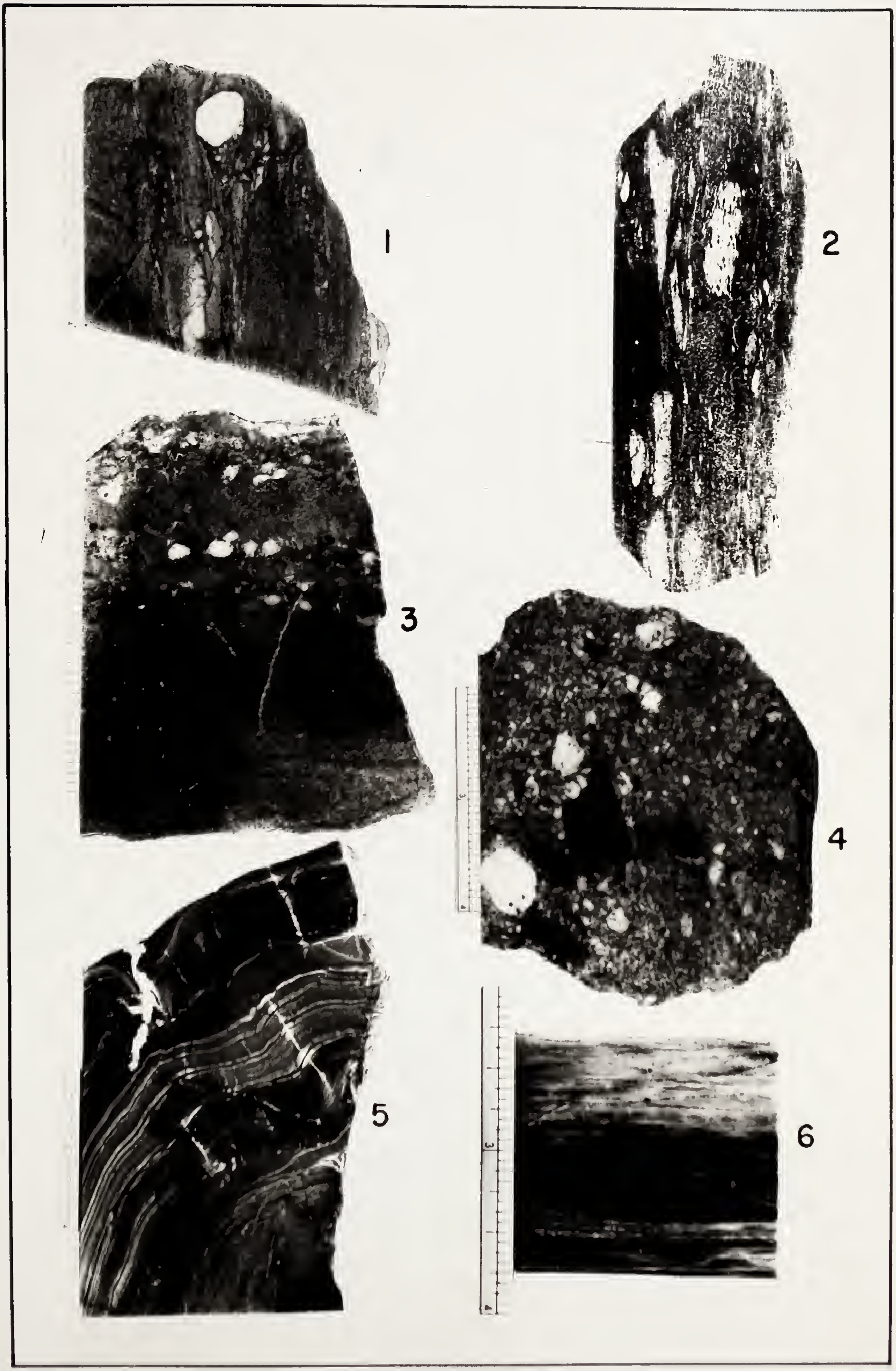

PLATE V

THIN SECTION PHOTOMICROGRAPHS OF SOME STANDARD REFERENCE ROCKS

1. Feldspathic wacke, showing good clastic texture. Thin section 60-709-2. Crossed nicols, 65x.

2. Mica-quartz arenite, showing development of sutured grain boundaries, highly recrystallized. Thin section 60-146-1. Crossed nicols, 65x.

3. Quartzose siltstone, showing graded bed. Top of graded bed is sericitic. Thin section 60-147-2. Crossed nicols, 85x.

4. Quartz basalt, showing felty groundmass. Thin section 60-711-5. Crossed nicols, 65x.

5. Tuffaceous metasedimentary rock, showing xenoclasts of zoned plagioclase. Thin section 60-716-3. Crossed nicols, 25x.

PLATE V

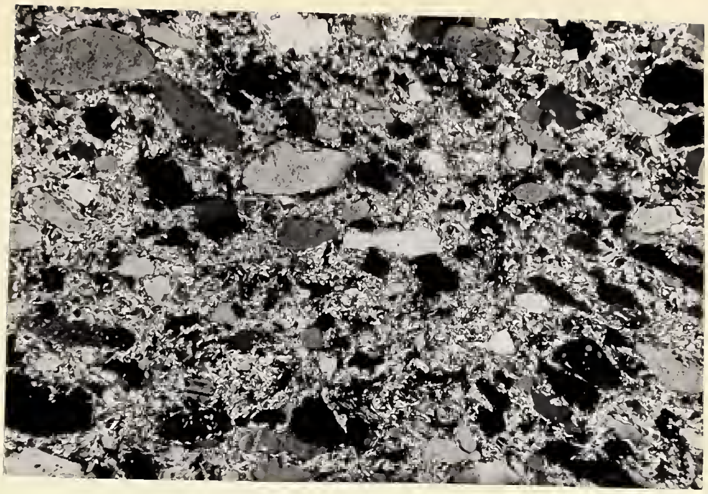

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PLATE VI

PHOTOMICROGRAPHS OF HEAVY MINERALS

1. Anatase--authigenic, striations on basal cleavage face. From sample 60-146-1. 340x

2. Anatase--authigenic, striations on basal cleavage face. From sample 60-146-1. 660x

3. Rutile--authigenic, yellow, oblique striations. From sample 60-709-2. 440x

4. Rutile--authigenic, polysynthetic twinning. From sample 60-717-4. 820x

5. "Normal" zircon--broken euhedron, clear core, cracks mainly perpendicular to the c-axis. From sample 60-716-3. 420x

6. Hyacinth zircon--broken euhedron, zoned. From sample 60-716-3. 270x

7. "Normal" zircon--euhedron, prismatic, pyramid terminations well developed, mineral inclusion. From sample 60-709-2. 270x

8. "Normal" zircon--very well rounded, inclusions. From sample 60-717-4. 340x

9. "Normal" zircon--rod shape, rounded, mineral inclusion oriented parallel with c-axis. From sample 60-709-2. 440x

10. Malacon-cored zircon--hyacinth overgrowth, subrounded. From sample 60-709-2. 440x

11. Double hyacinth-cored zircon--malacon overgrowth, radiating cracks in second hyacinth core. From sample 60-146-1. 340x

12. Hyacinth zircon--zoned. From sample 60-716-3. 440x

PLATE VI

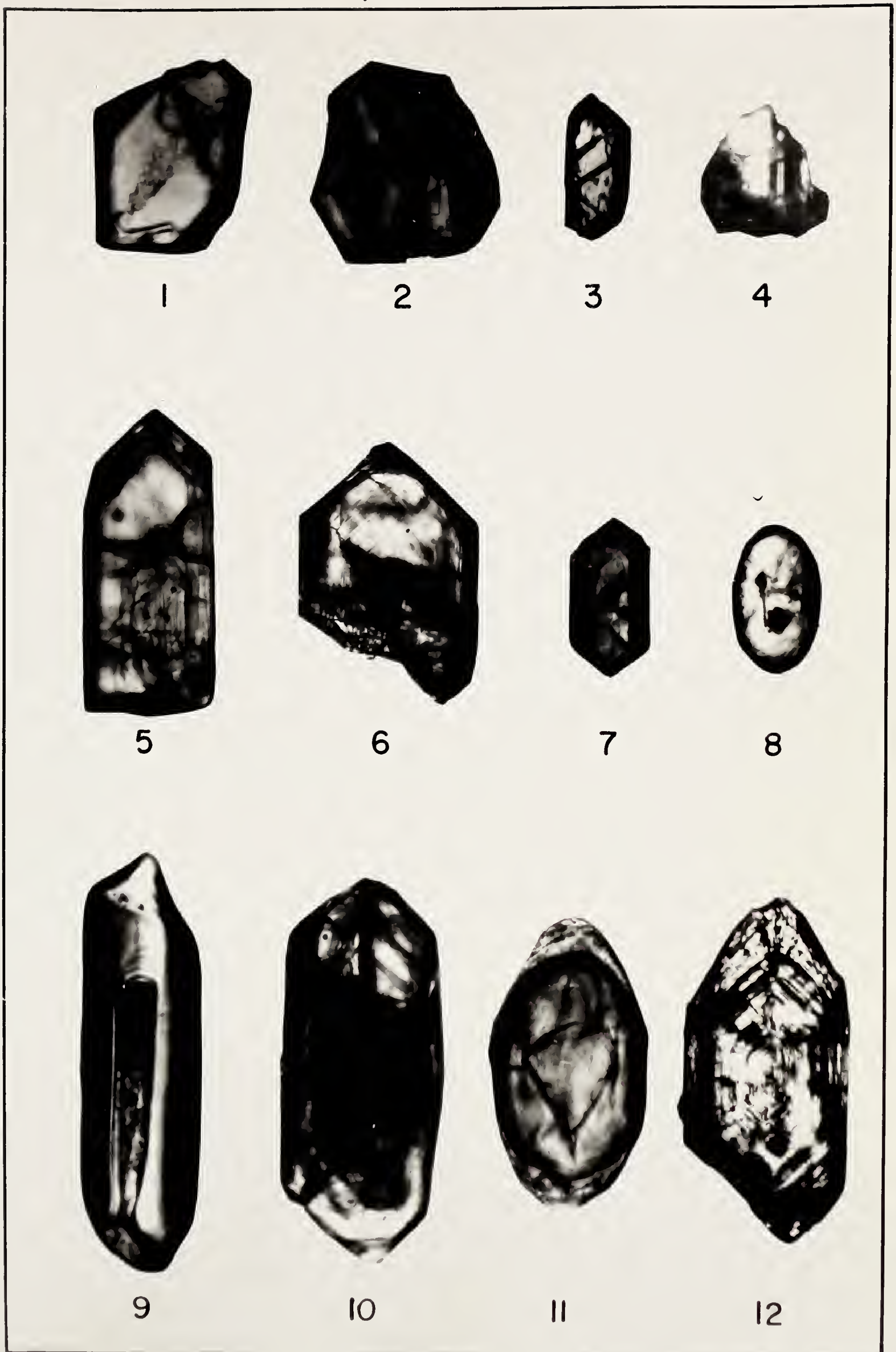
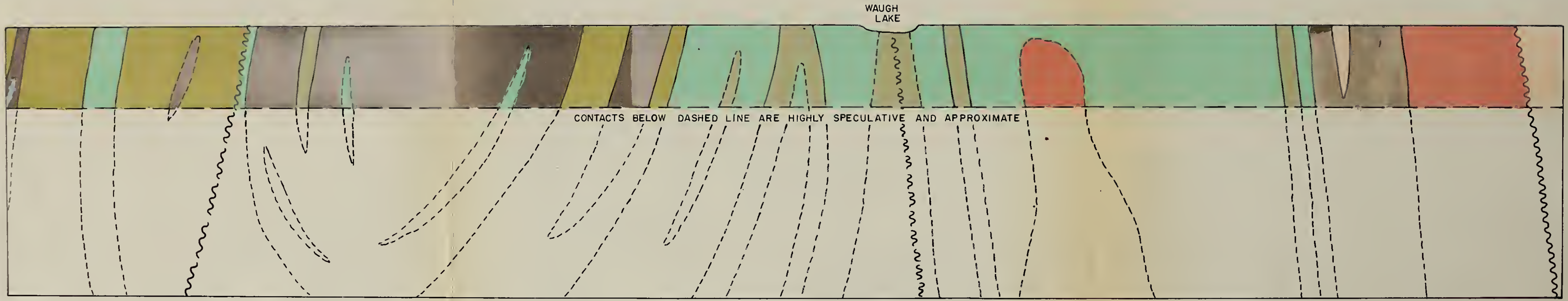


Figure 8

DIAGRAMMATIC GEOLOGICAL SECTION, TAKEN ALONG LATITUDE 59°49', LOOKING NORTH



NOTE: FOR LEGEND, SEE ACCOMPANYING GEOLOGICAL MAP
VERTICAL SCALE AND DIP OF CONTACTS ARE EXAGGERATED

Horizontal Scale: Four Inches to One Mile

MA

MAP I

LEGEND

PRECAMBRIAN

METASEDIMENTARY AND DERIVED ROCKS

QUARTZITE, pure and impure, grey and green; including greywacke, siltstone, phyllonite, biotite-sericite schist, minor milky quartz pods, feldspar augen, granite and pegmatite lenses, ferruginous zones. Bands of mylonite.

BIOTITE SCHIST, with abundant quartz, some sericite; including slate, phyllite, phyllonite, quartzite, minor milky quartz pods, feldspar augen, granite and pegmatite lenses, ferruginous zones. Sericite, chlorite schist with quartzite lenses, fragments, phyllonitic; minor quartz pods, crush conglomerate.

SILICEOUS CONGLOMERATE, with abundant subangular to subrounded quartz and quartzite pebbles, 1/8"– 2" in size; matrix dominantly silt, often bedded.

SERICITIC, PORPHYROCLASTIC PHYLLONITE, feldspar augen; typically sheared, conglomeratic megoscopic appearance; with phyllite, quartzite, crush conglomerate.

GRANITIC METASEDIMENTS, rich in biotite, pink and white feldspars; highly injected, granitized; abundant pegmatitic and granitic lenses, pods, bands.

IGNEOUS AND HIGHLY GRANITIZED ROCKS

BASIC ROCKS, various basic rocks including greenstone, amphibolite, basalt, diabase, tuff.

BIOTITE GRANITE A, with white or grey euhedral feldspar megacrysts, 1/2"– 1" in size, in a foliated biotite-rich matrix; including minor aplite, microgranite.

BIOTITE GRANITE B, with white or grey euhedral feldspar megacrysts, 1/2"– 1" in size; including minor aplite, microgranite and massive grey granite.

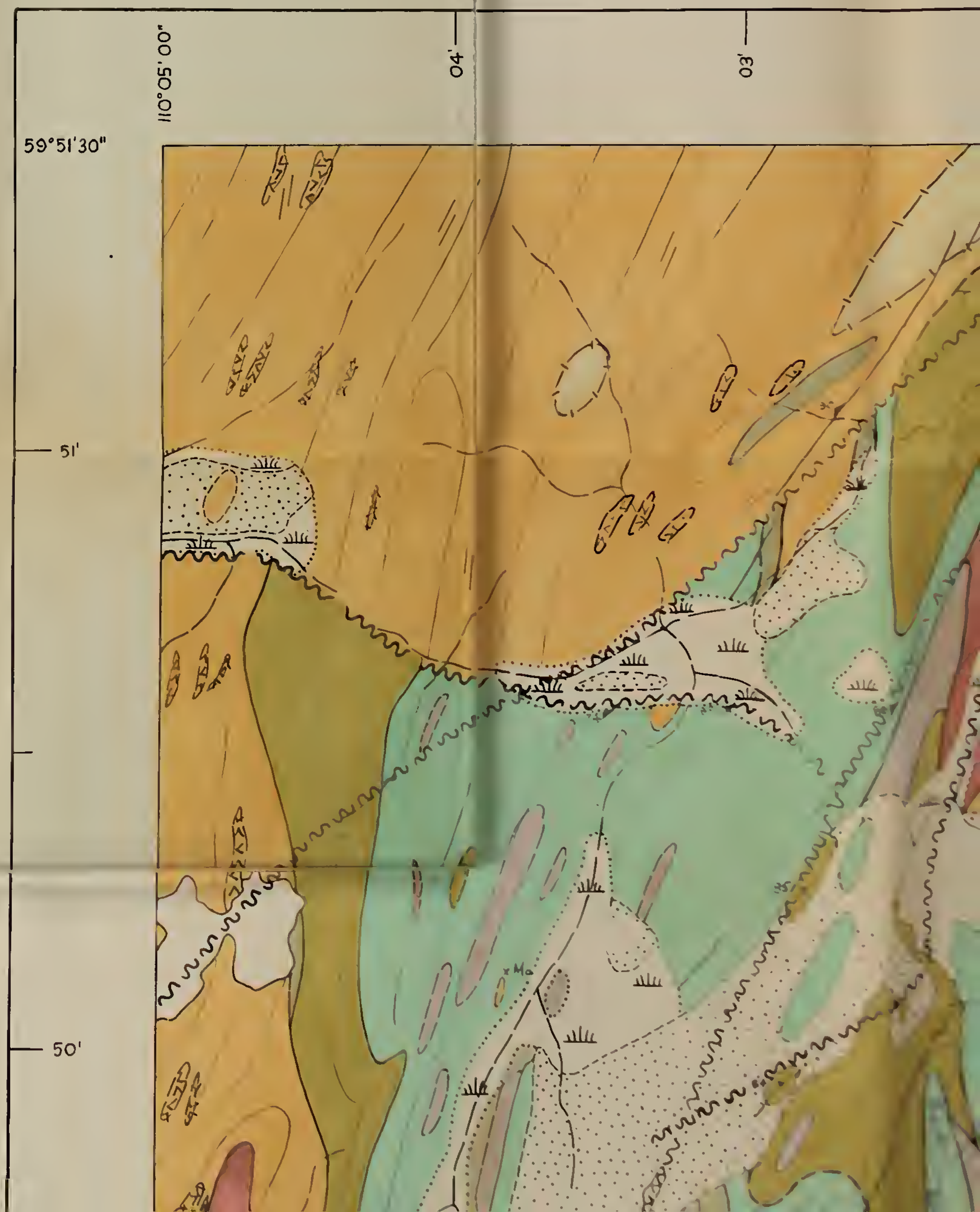
BIOTITE GRANITE C, with white or grey subhedral to anhedral feldspar megacrysts, 1/4"– 1/2" in size, in a foliated matrix; including minor aplite, microgranite.

BIOTITE GRANITE GNEISS, with some chlorite; including minor massive granite, alaskite. Lenses of schist, quartzite, amphibolite. Bands of mylonite.

AMPHIBOLITE, including biotite amphibolite, hornblendite; banded to massive.

T

NORTHEASTER



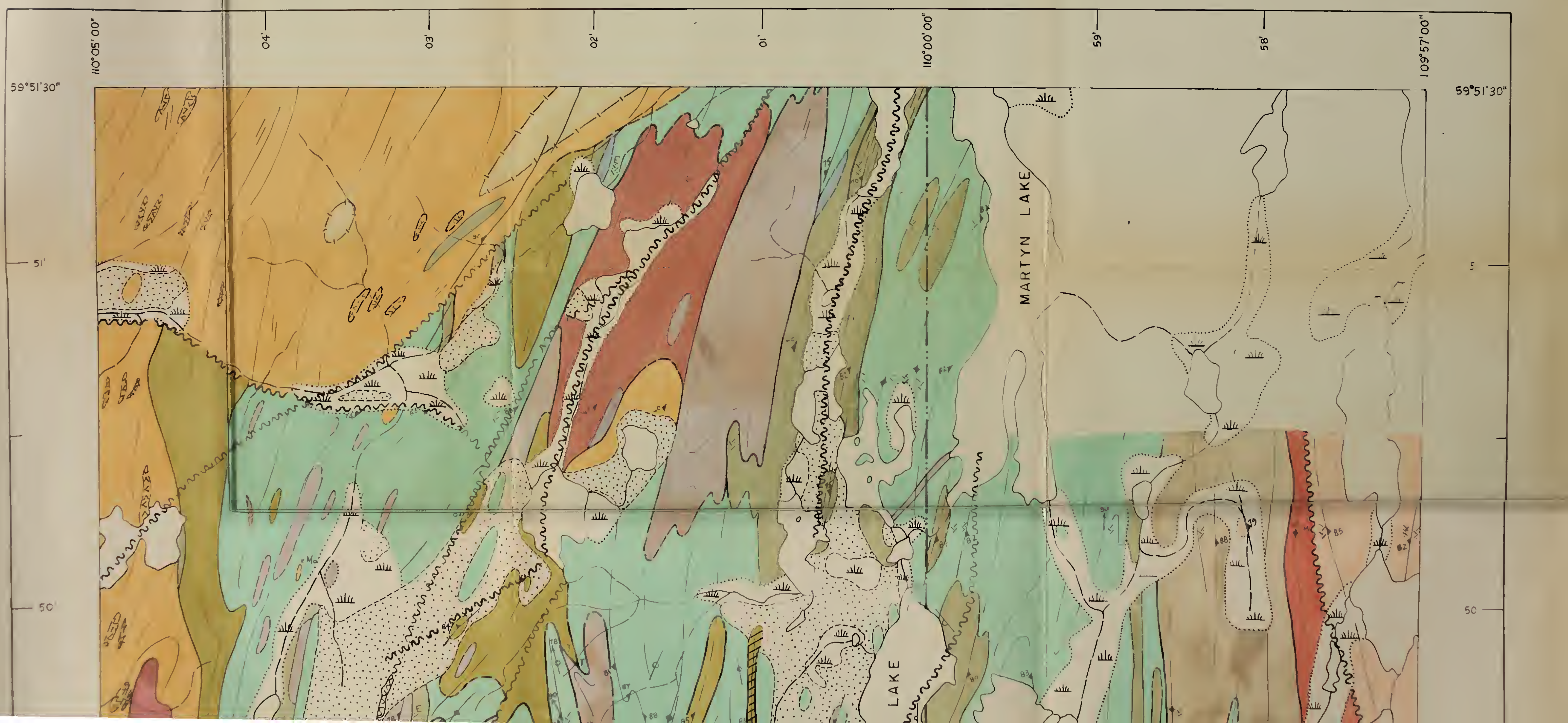
GEOLOGICAL MAP
OF
THE WAUGH LAKE AREA

NORTHEASTERN ALBERTA AND NORTHWESTERN SASKATCHEWAN

Scale: Four Inches to One Mile

Miles

0 1/4 1/2 3/4 1



BIOTITE GRANITE B, with white or grey euhedral feldspar megacrysts, 1/2" – 1" in size; including minor aplite, microgranite and massive grey granite.

BIOTITE GRANITE C, with white or grey subhedral to anhedral feldspar megacrysts, 1/4" – 1/2" in size, in a foliated matrix; including minor aplite, microgranite.

BIOTITE GRANITE GNEISS, with some chlorite; including minor massive granite, alaskite. Lenses of schist, quartzite, amphibolite. Bands of mylonite.

AMPHIBOLITE, including biotite amphibolite, hornblendite; banded to massive.

BIOTITE GRANITE, with pink and red feldspars, minor sericite; massive. Muscovite granite (m), with abundant pink and white feldspars, minor biotite; massive. Feldspar megacryst (p) – bearing biotite granite.

WHITE BIOTITE GRANITE, including white microgranite; white feldspars, siliceous; poorly foliated to massive, medium to fine grained.

SHEARED LEUCOCRATIC GRANITE, with white to pink feldspars, medium to fine grained, typically sheared; minor biotite; muscovite often abundant.

GRANITE PEGMATITE, with pink and red feldspars, biotite; massive.

Geological boundary (defined, approximate)

Geological boundary, gradational

Schistosity, gneissosity, foliation (defined, dip known, dip vertical, lineation) 70 60 80

Tight folds (structural trend)

Fault (defined, approximate, assumed)

Shear, shear zone

Breccia

Mylonite

Bedding ... dip known, top known 80

... dip known, top known, overturned 80

... dip unknown, top known

... dip unknown, top unknown

Molybdenite ... Mo

Tourmaline ... T

Epidote ... E

Arsenopyrite ... As

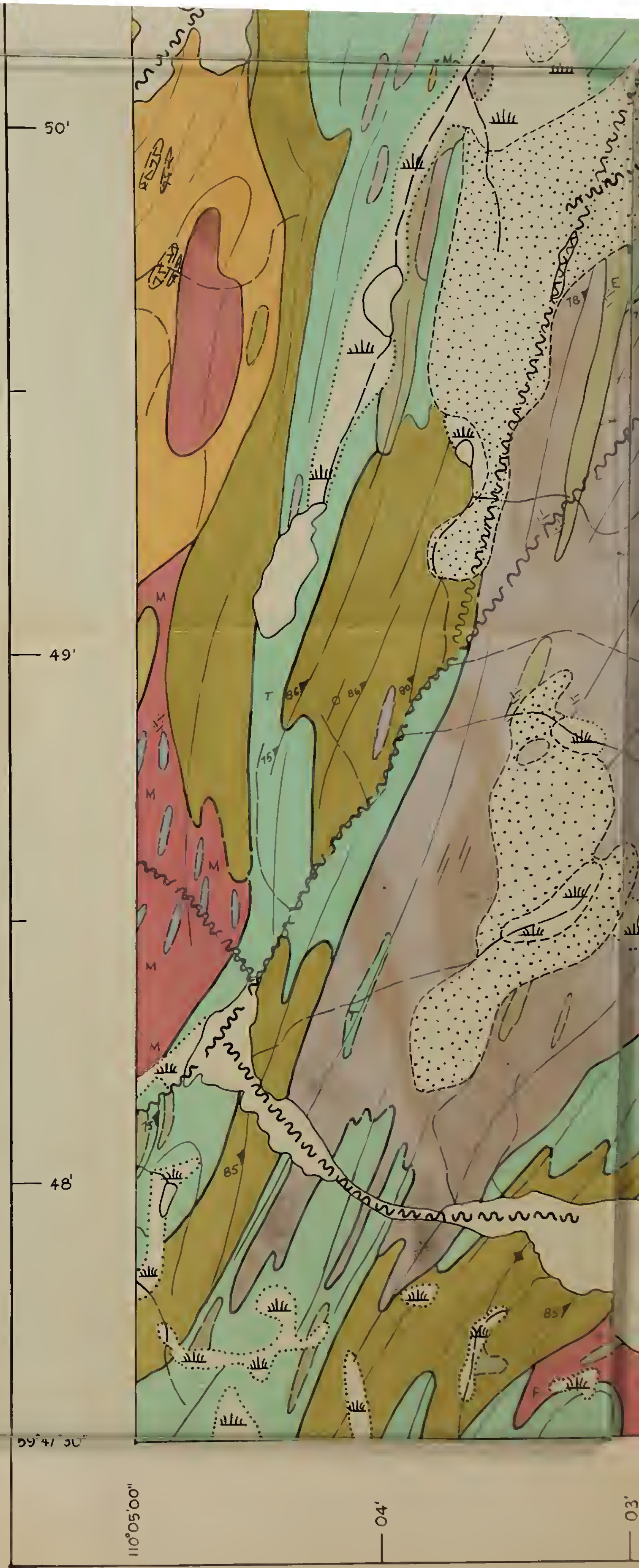
Geology by Roy Y. Watanabe and John D. Godfrey, 1960

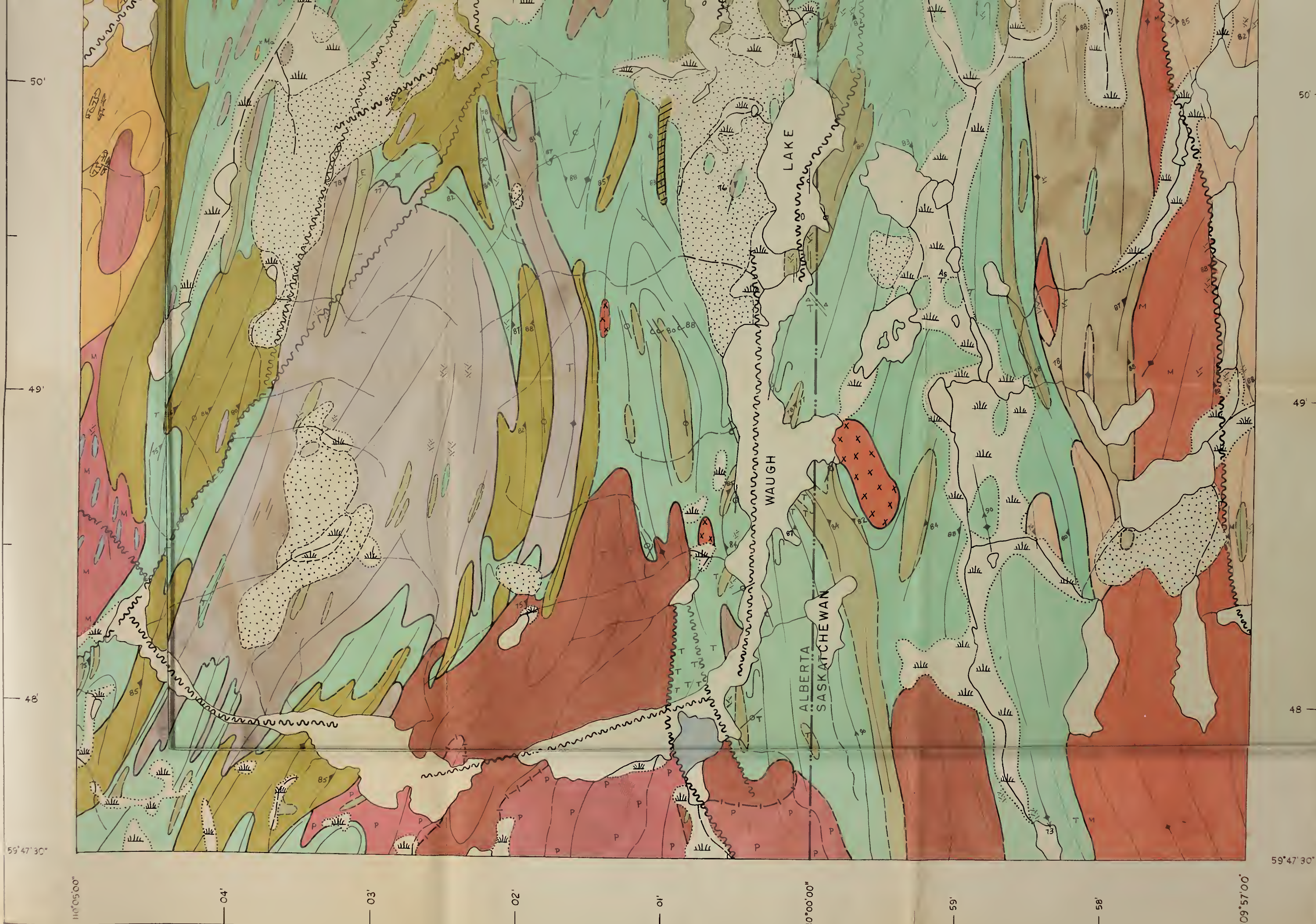
Sand covered area

Muskeg

Drainage (permanent, intermittent)

Provincial boundary





LAKE
WAUGH
ALBERTA
SASKATCHEWAN
50'
49'
48'
59°47'30"
110°05'00"
04'
03'
02'
01'
110°00'00"
59'
58'
109°57'00"

MAP II

SAMPLE LOCATION MAP
OF
THE WAUGH LAKE AREA

NORTHEASTERN ALBERTA AND NORTHWESTERN SAS

Scale: Four Inches to One Mile

Miles

0 1/4 1/2 3/4 1

LEGEND

• Sample Location

⊙ Thin Sectioned Sample

MAP II

SAMPLE LOCATION MAP
OF
THE WAUGH LAKE AREA

NORTHEASTERN ALBERTA AND NORTHWESTERN SASKATCHEWAN

Scale: Four Inches to One Mile

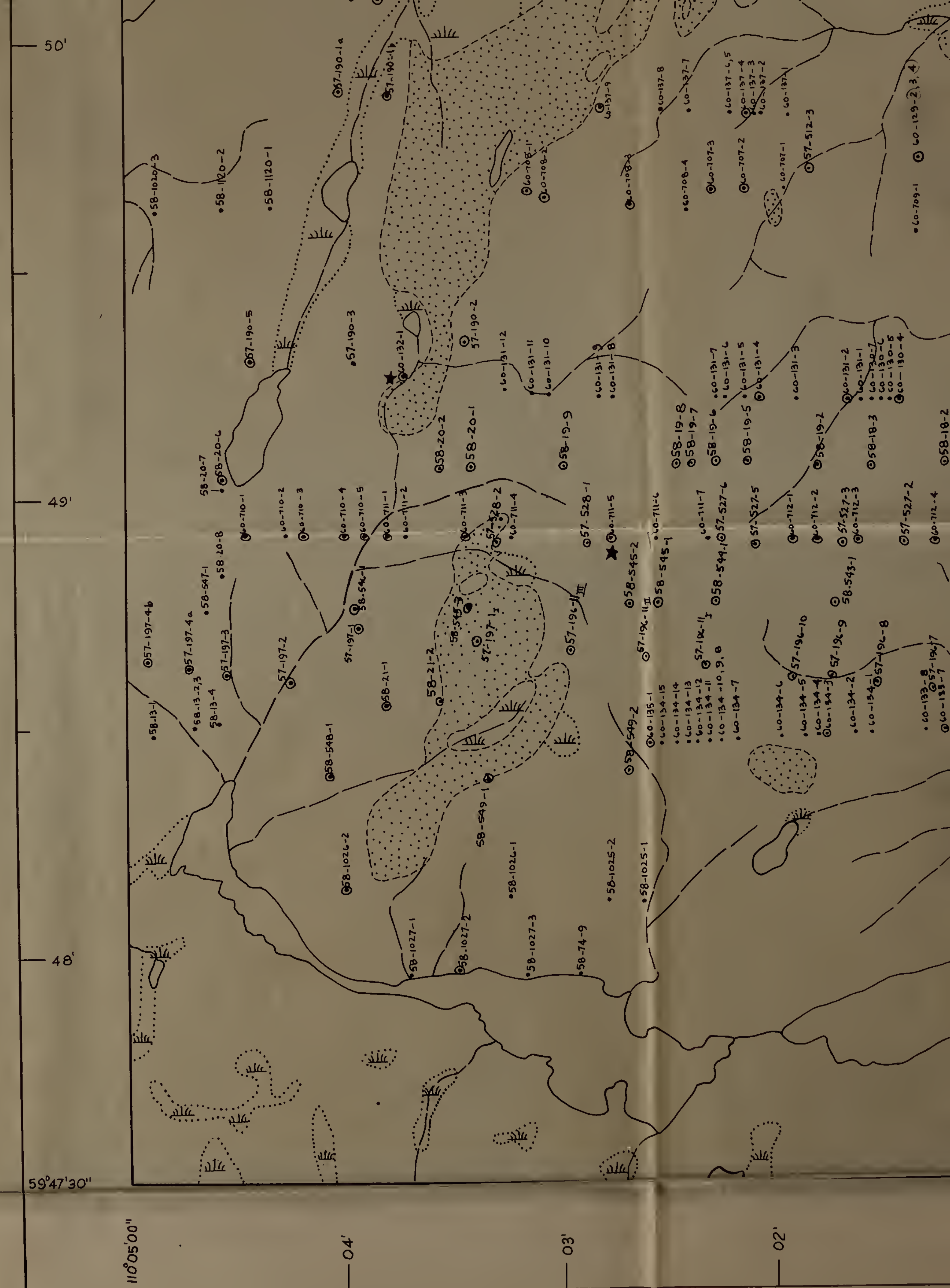
Miles

0 1/4 1/2 3/4 1

LEGEND

- • Sample Location
- ⊙ Thin Sectioned Sample
- ★ Standard Reference Rock Sample

Note: This Sample Location Map is intended to serve as an overlay on the accompanying Geological Map.



50'
49'
48'
59°47'30"
110°05'00"
04'
03'
02'
01'
110°00'00"
59'
58'
109°57'00"
59°47'30"